

Appendix A

Hydrogeological Report

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List of Acronyms

A1W	Large Ship Reactor Prototype (<u>1st</u> <u>A</u> ircraft Carrier design by <u>W</u> estinghouse)
ARAR	Applicable or Relevant and Appropriate Requirements
asl	Above Sea Level
bls	Below Land Surface
BNA	Base Neutral Acids
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFA	Central Facilities Area
CFR	Code of Federal Regulations
DFA	Design, Follow, and Administrative
DOE	Department of Energy
ECF	Expended Core Facility
EPA	Environmental Protection Agency
°F	Degrees Fahrenheit
F/L	Fluvial/Lacustrine
FFA/CO	Federal Facilities Agreement and Consent Order
GMN	Groundwater Monitoring Network
HI	Hazard Index
ICR	Increased Cancer Risk
IDHW	Idaho Department of Health and Welfare
INEEL	Idaho National Engineering and Environmental Laboratory
INTEC	Idaho Nuclear Technological Center
IWD	Industrial Waste Ditch
LCS	Laboratory Control Sample
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MDL	Method Detection Limit
MEMO	Monitoring Efficiency Model
μ	Micro (a prefix denoting a one-millionth part or 10 ⁻⁶)
mg	Milligrams
N	Nitrogen
NCP	National Oil and Hazardous Substance Pollution Contingency Plan
NPL	National Priorities List
NR	Naval Reactors
NRF	Naval Reactors Facility
O&M	Operations and Maintenance
OU	Operable Unit
PAH	Polynuclear Aromatic Hydrocarbons
PCE	Tetrachloroethylene
pCi	Picocurie; one trillionth (10 ⁻¹²) of a curie, a measure of the amount of radioactivity
pCi/g	Picocuries Per Gram
pCi/L	Picocuries Per Liter
ppb	Parts Per Billion
ppbv	Parts Per Billion by Volume
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act.
RD/RAWP	Remedial Design/Remedial Action Work Plan
RI/FS	Remedial Investigation and Feasibility Study
S1W	Submarine Thermal Reactor Prototype (<u>1st</u> <u>S</u> ubmarine design by <u>W</u> estinghouse)
S5G	Submarine Reactor Plant Prototype (<u>5th</u> <u>S</u> ubmarine design <u>G</u> eneral Electric)
SL	Sewage Lagoon

SMCL	Secondary Maximum Contaminant Level
SRP	Snake River Plain
SRPA	Snake River Plain Aquifer
TCA	1,1,1-Trichloroethane
TCE	Trichloroethylene
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TOX	Total Organic Halogens
TRA	Test Reactor Area
µg/m³	Micrograms per Cubic Meter
µS/cm	Microseimens per Centimeter
USGS	United States Geological Survey
VOC	Volatile Organic Compound
v/v	Volume of Constituent Per Volume of Sample
WAG	Waste Area Group
WEC	Westinghouse Electric Company
WRIR	Water Resource Investigation Report

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1.0 Introduction

1.1 Overview

Over the past decade, environmental monitoring personnel at the Naval Reactors Facility (NRF) have collected a variety of geological and hydrogeological data. These data, in conjunction with other types of data, have been used to perform two Remedial Investigation and Feasibility Studies (RI/FSSs), and numerous less intensive studies (Track 1 and Track 2) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). With these studies complete, environmental monitoring continues to ensure compliance with regulations and verify conditions remain as expected.

Four mediums are targeted for monitoring at NRF. These are air, soil, vegetation, and water. This report deals with the water medium. Currently NRF collects groundwater samples from monitoring wells, effluent samples (both from the Industrial Waste Ditch (IWD) and the sewage lagoons), and drinking water samples from production wells. Although this report primarily concentrates on groundwater, all other data are considered and used as appropriate. Ultimately, the various types of water data are used to assess NRF's monitoring program in accordance with agreements made between the U.S. Environmental Protection Agency (EPA), the Division of Environmental Quality Idaho Department of Health and Welfare (IDHW), and U.S. Department of Energy (DOE), Office of Naval Reactors, and to act as an early warning against any potential environmental release.

In addition to data gathered from the various water samples, other types of data have been collected and are available for analysis. These include hydrogeological, geological, meteorological, and seismological data. Using all available data, the purpose of this report is to improve NRF's ability to monitor, detect, and if need be take appropriate actions to safeguard human health and the environment. Furthermore, this report is also intended to increase the overall knowledge of the geological framework associated with NRF.

This report is divided into six sections. Section 1 provides an overview of the report and a summary of groundwater monitoring at NRF. Section 2 contains climate and hydrogeologic topics. Section 3 discusses topics related to long-term data analysis, including trend analysis, background data analysis, and similar topics. Section 4 discusses results of the most recently evaluated groundwater data. Section 5 provides a summary of the analysis and interpretation of previously covered information. Section 6 discusses knowledge gaps at NRF and possible evaluations that may be required in the future to ensure monitoring goals at NRF are achieved.

1.2 Monitoring Summary

NRF has been routinely collecting groundwater monitoring data since 1989. Since 1994, this monitoring has served to comply with agreements between the EPA, IDHW, and DOE, Office of Naval Reactors. These agreements were the result of investigations associated with two RI/FSSs and numerous Track 1 and Track 2 studies under CERCLA. During 1989, the NRF groundwater monitoring network consisted of various NRF domestic water supply wells, various United States Geological Survey (USGS) wells, and an INEL water supply well. The reliability of some of the data collected from these wells was considered to be low since these wells, with the exception of USGS-102, were not specifically designed to support monitoring of the upper portion of the aquifer, the portion of the aquifer most likely to contain contaminants released

from above ground sources. In 1991, two wells built by NRF (NRF-6 and NRF-7) were added to the monitoring network. These wells, and wells added subsequently by NRF, are designed to monitor at a maximum the upper 50 feet of the aquifer. In 1996, NRF added six new wells to the monitoring network (NRF-8 through NRF-13). Furthermore, NRF domestic water supply wells, two USGS wells, and the INEL water supply well, were removed from the network. Figure A-1 shows the current configuration of the NRF groundwater monitoring network.

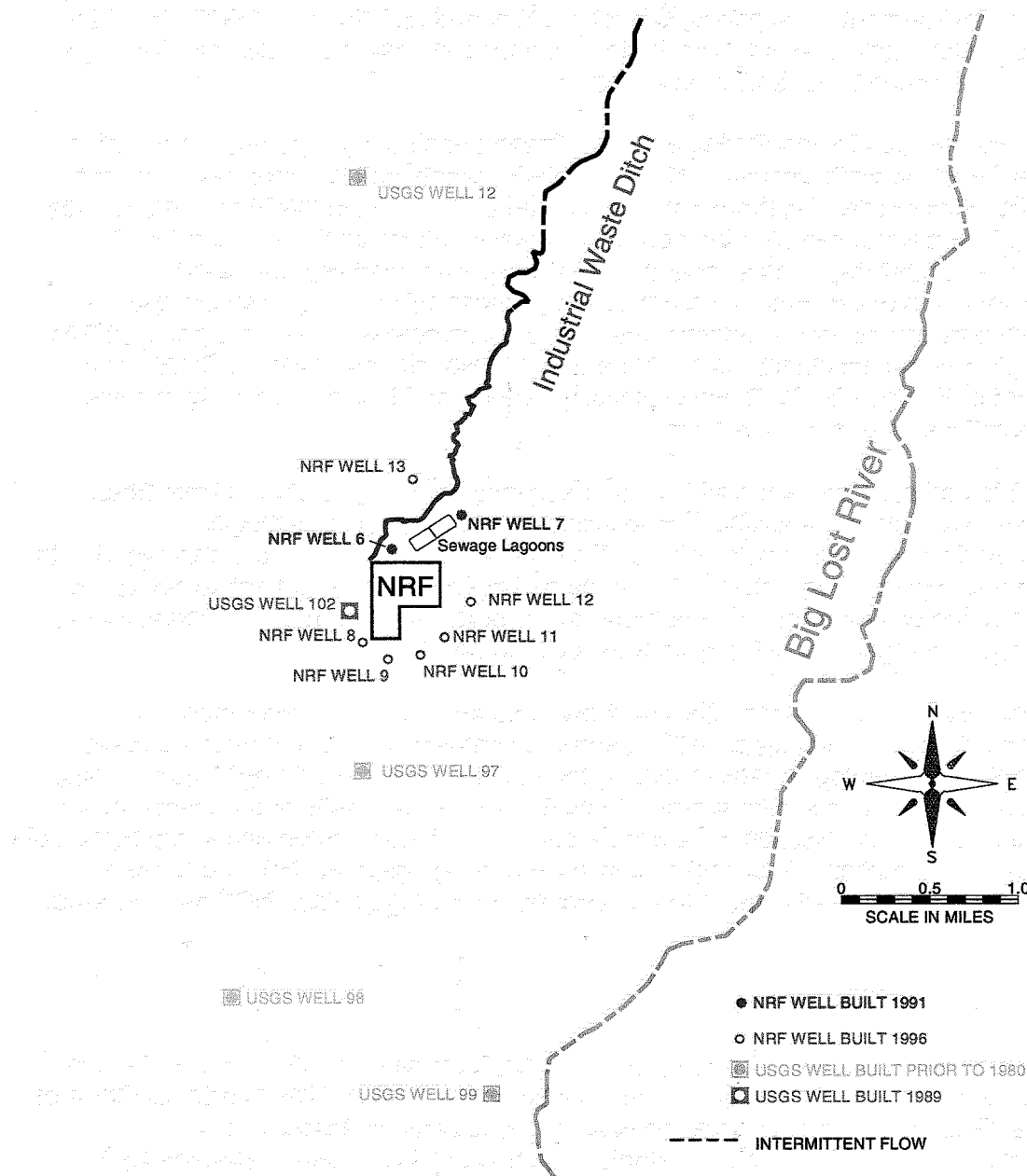


Figure A-1 Location of NRF Groundwater Monitoring Wells

As an aid in analyzing groundwater data collected at NRF, the monitoring wells have been divided into four groups. These groups are referred to as follows: Regional Upgradient Wells (USGS-12 and NRF-7); Effluent System Monitoring Wells (NRF-6 and NRF-13); Site Downgradient Wells (NRF-8 through NRF-12 and USGS-102); and Regional Downgradient Wells (USGS-97 through USGS-99). Each monitoring group is designed to monitor a specific portion of the aquifer surrounding NRF.

The Regional Upgradient Wells monitor water that is unaffected by NRF activity. However, water in these wells may be affected by other Idaho National Engineering and Environmental Laboratory (INEEL) activities or farming. The Effluent System Monitoring Wells are designed to monitor waters affected by the NRF IWD and the NRF sewage lagoons. The Site Downgradient Wells were located to monitor the impact that ongoing and past operations at NRF, including the IWD, sewage lagoons, and inactive landfill areas are having on the Snake River Plain Aquifer (SRPA) beneath NRF. Finally, the Regional Downgradient wells are placed downgradient of NRF to be a secondary measure of the effects that NRF may have on the SRPA, and to provide data to compare to Regional Upgradient data.

Currently NRF analyzes groundwater samples for 29 inorganic and nutrient constituents, 5 radiological parameters, and 26 volatile and semi-volatile organic constituents. Table A-1 lists the groundwater constituents that are monitored, and the analytical method, Maximum Contaminant Level (MCL), and Maximum Contaminant Level Goal (MCLG) associated with each constituent. MCLs and MCLGs are in accordance with the EPA's Safe Drinking Water Act.

Table A-1 Groundwater Monitoring Constituents			
Constituent	Analytical Method	MCL (mg/L)	MCLG (mg/L)
Aluminum	6010A ICP	0.2	*
Antimony	6020 ICP/MS	0.006	0.006
Arsenic	6020 ICP/MS	0.05	*
Barium	6020 ICP/MS	2	2
Beryllium	6020 ICP/MS	0.004	0.004
Cadmium	6020 ICP/MS	0.005	0.005
Calcium	6010 ICP	*	*
Chromium	6020 ICP/MS	0.1	0.1
Copper	6020 ICP/MS	1.3	1.3
Iron	6010A ICP	0.3	*
Lead	6020 ICP/MS	0.015	0
Magnesium	6010A ICP	*	*
Manganese	6020 ICP/MS	0.005	*
Mercury	7476A	0.002	0.002
Nickel	6020 ICP/MS	0.1	0.1
Potassium	6010 ICP	*	*
Selenium	6020 ICP/MS	0.05	0.05
Silver	6020 ICP/MS	0.1	*
Sodium	6010A ICP	*	*
Thallium	6020 ICP/MS	0.002	0.0005
Zinc	6020 ICP/MS	5	*
Sulfate	300	250	*
Chloride	300	250	*

Table A-1 Groundwater Monitoring Constituents (continued)			
Constituent	Analytical Method	MCL (mg/L)	MCLG (mg/L)
Nitrate (as N)	353.2	10	10
Nitrite (as N)	354.1	1	*
Total Kjeldahl Nitrogen (TKN)	351.2	*	*
Phosphorus	365.3	*	*
Total Organic Carbon (TOC)	415.1	*	*
Total Organic Halogens (TOX)	9020B	*	*
Gross Alpha (as Thorium 230)	EPA 900	1.5 pCi/L	*
Gross Beta (as Cs 137)	EPA 900	5 pCi/L	*
Strontium-90	EPA 905	8 pCi/l	*
Tritium	R-1173-76	20,000 pCi/L	*
Quantitative Isotopic Gamma	EPA 901.1	*	*
Benzene	524.2	0.005	0
Carbon Tetrachloride	524.2	0.005	0
1,1-Dichloroethane	524.2	*	*
1,2-Dichloroethane	524.2	0.005	0
1,1-Dichloroethylene	524.2	0.007	0.007
Cis-1,2-Dichloroethylene	524.2	0.07	0.07
Trans-1,2-Dichloroethylene	524.2	0.1	0.1
Ethylbenzene	524.2	0.7	0.7
Methylene Chloride	524.2	0.005	0
1,1,2,2-Tetrachloroethane	524.2	*	*
Tetrachloroethylene	524.2	0.005	0
Toluene	524.2	1	1
1,1,1-trichloroethane	524.2	0.2	0.2
Trichloroethylene	524.2	0.005	0
Trichlorofluoromethane	524.2	*	*
Vinyl Chloride	524.2	0.002	0
Xylenes (total = o+p+m)	524.2	10	10
Benzo(b)fluoranthene	525.1	*	*
Benzo(a)pyrene	525.1	0.0002	0
Di-n-butylphthalate	525.1	*	*
Di(2-ethylhexyl)phthalate	525.1	0.006	0
Di-n-octylphthalate	525.1	*	*
Isophorone	525.1	*	*
Naphthalene	525.1	*	*
Phenanthrene	525.1	*	*
Pyrene	525.1	*	*

*No MCL or MCLG has been set for this constituent

2.0 Climate and Hydrogeological Data

This section discusses climatic and hydrogeologic processes that are important in the understanding of the hydrogeology of NRF. A good understanding of hydrogeology is useful in interpreting groundwater data collected from the NRF groundwater monitoring network. The following sub-sections will discuss changes in water table elevations in the SRPA and factors, such as climate, that affect these changes.

2.1 Climate

The water table elevation in the SRPA is very sensitive to precipitation and temperature at the INEEL and the surrounding watershed basin. Since only a small percentage of precipitation that hits the ground actually infiltrates into the subsurface (estimated to be 1 to 3 inches per year of the 6 to 10 inches annual precipitation; Garabedien, 1992), the main source of recharge to the SRPA at the INEEL is from the Big Lost River, Little Lost River, and Birch Creek. Factors that affect runoff are important to understanding NRF hydrogeology.

Collection of climatological data at the INEEL Central Facilities Area (CFA) has occurred since the early 1950s. These data are indirect predictors of future changes in water table elevations. The interaction between climate and water table elevation at NRF is complex. The use of graphs is essential in establishing trends and in making visual correlations in the data. The climatological data associated with NRF is discussed below.

Figure A-2 is a map of the INEEL showing the location of NRF and the playa lakes located north of NRF. The playas are situated at the lowest elevation of a closed basin. Water is introduced into this basin in four ways: by direct flow from the Big and Little Lost Rivers and Birch Creek; and by precipitation falling directly on the playas. When the flux of water into the closed basin exceeds the flux out of the basin, a lake forms and begins to expand outward. Flux out of the basin follows two pathways: infiltration through the soil and evapotranspiration. The expansion of the playa lake continues until flux in and flux out are the same. For the past several hundred years, the natural state of the playas is dry.

Only during wetter/cooler periods will water continuously reside in the playas. Since 1972, standing water in the playas has occurred twice. Once in the early to mid 1980s (a span of approximately 5 years), and again during the late 1990s (a span of approximately 3 years). The playas are hydrologically upgradient to NRF; therefore, the water table at NRF is affected when water reaches the playas for an extended period. Factors that enhance water movement to the playas are extensive snow pack in conjunction with rapid melting, and periods of high precipitation coupled with low to moderate evaporation rates. Temperature indirectly influences these factors.

Temperature is an important contributor to subsurface recharge for several reasons. First, lower wintertime temperatures coupled with higher precipitation results in a deeper snow pack. Second, lower temperatures cause the ground to become frozen. The longer the ground is frozen the less infiltration occurs. Third, less sublimation occurs with lower temperatures. Temperature is also the primary factor that influences evapotranspiration. Finally, higher temperatures promote more evapotranspiration.

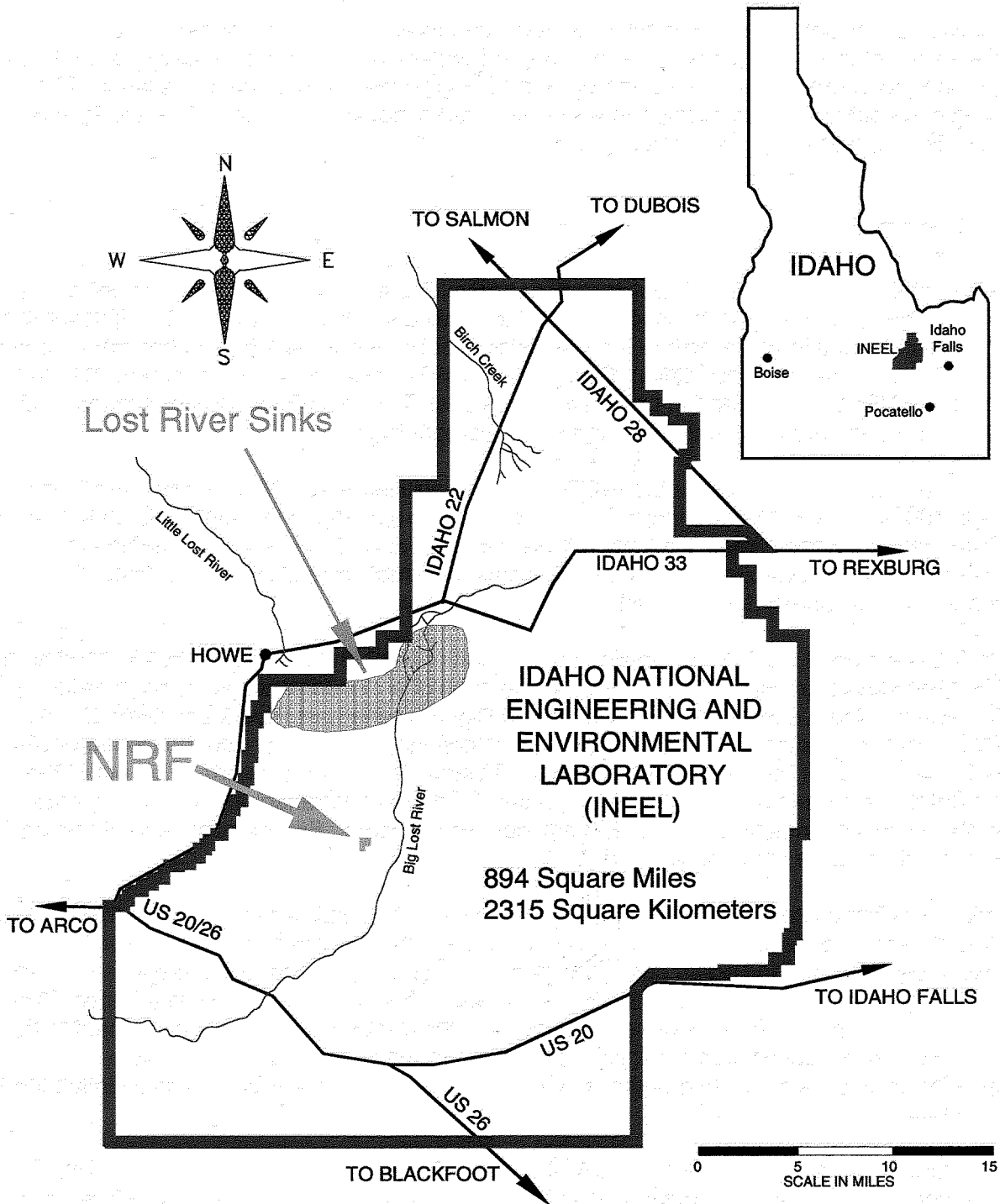


Figure A-2 Location of the NRF on the INEEL in Relation to the Lost River Sinks

Attachment 8 of this document lists the Average Maximum Temperature, the Average Minimum Temperature, Average Temperature, and precipitation amounts since January 1972. These data reveal several interesting and informative statistics. Since 1972, the hottest summer occurred in 1988 with an average temperature of 68.7 degrees Fahrenheit (°F). This number is derived by averaging the daily high and low temperatures for the months of June, July and August. The coldest winter occurred during 1984-1985 (December, January, and February) with an average temperature of 7.9 °F. This number is calculated as above except winter months are used. The coolest summer occurred in 1993 with an average temperature of 58.6 °F. Finally, the warmest winter occurred in 1980-1981 with an average temperature of 25.5 °F. These dates are hydrologically significant. The year of the warmest winter, 1980-81, was near the beginning of the resumption of flow in the Big Lost River channel. Flow continued in the channel almost constantly for the next five years. The year of the coldest winter, 1984-85, marks the beginning of the current warming trend and the beginning of a seven year drought. The year 1988, that coincides with the hottest summer, marks what is probably the height of the seven year drought, and the year 1993, the year of the coolest summer, is considered the end of the drought.

Figure A-3 is a graph showing the average monthly temperature at CFA. These data encompass the period from January 1, 1972 to July 2000. This graph shows several trends. First, the average monthly temperature appears to be steadily rising over the period. The increase in temperature over this time span is approximately 3 °F; however, considering data since 1992 only, the average yearly temperature has been falling. The decade of the nineties has on average been warmer than the previous 20 years. The second trend is that seven of the past ten winters, including five of the past six, have been warmer than average. Over the past 28 years, the average summertime temperature was 64.4 °F and the average wintertime temperature was 18.9°F. The average wintertime temperature for the past five years was 21.8 °F. Another interesting fact is that warmer summers (particularly Julys) have been alternating with cooler Julys over the past eight or nine years. Warmer Julys occurred in 1992, 1994, 1996, and 1998, and cooler Julys in 1993, 1995, 1997, and 1999. The July of 1998 was the warmest of the nineties. Since 1992, every even-year July was warmer than the previous even-year July. Preliminary data indicate that this trend is continuing.

If the average wintertime temperature (over the months of December, January, and February) is determined for each year and plotted, the results displayed in Figure A-4 (lower portion) are created. This graph reveals three separate warming trends. The first occurred between 1972 and 1981, the second between 1985 and 1992, and the last between 1993 and the present. Each warming period was followed by an abrupt decline in temperature. From 1972 to present the average winter temperature has risen 3 to 4 °F.

The plot of average summertime temperatures (Figure A-4, upper portion) reveals a strong warming trend of approximately 4 °F between 1972 and 1992 as well. Since then, the graph can be interpreted as either a sharp cooling period followed by the beginning of a second warming period, or a continuation of the long-term warming trend described above. More data is required for positive trend identification. In combination, the last five years have been unusually moderate.

These patterns of temperature indicate that a long-term climatic change may have occurred during the 1990s. The duration and significance of the change is yet to be determined.

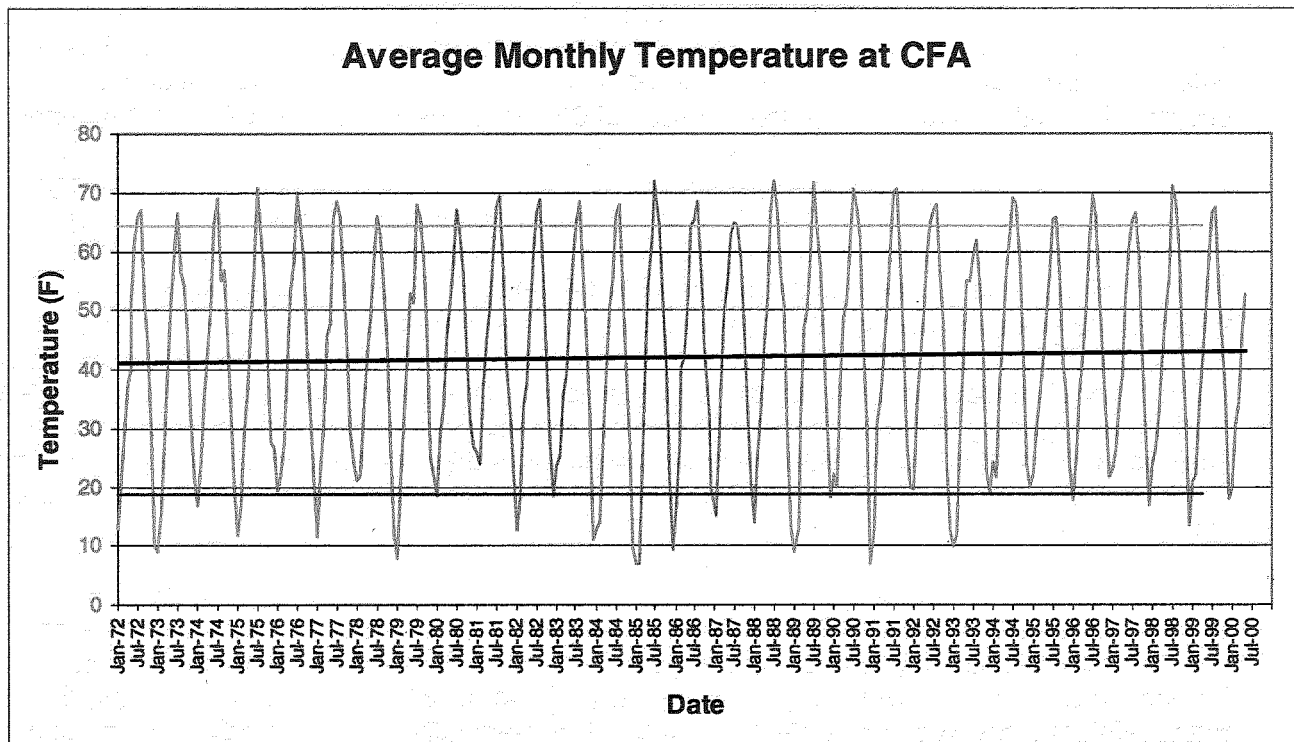


Figure A-3 Average Monthly Temperature at CFA

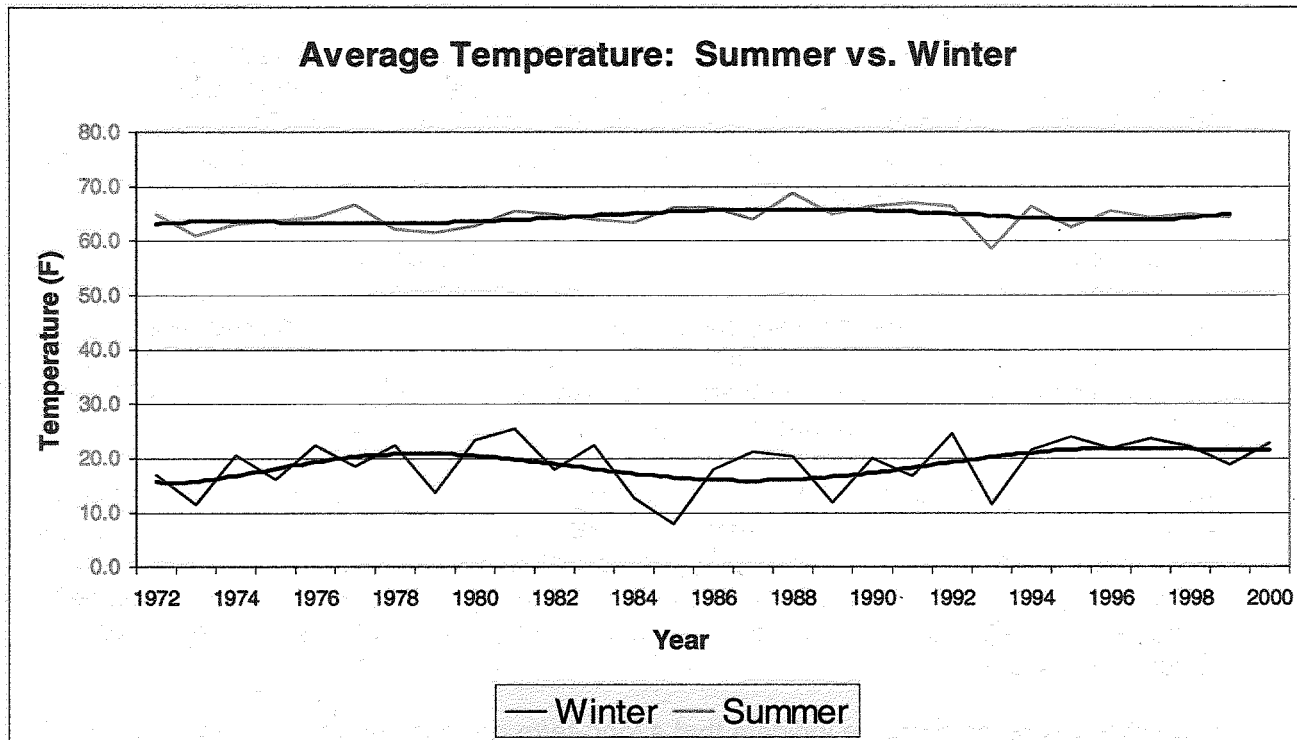


Figure A-4 Average Summertime Temperature vs. Average Winter Temperature

Over the past 28 years, the meteorological station at the Central Facilities Area at the INEEL has received an average of 8.77 inches of precipitation per year. CFA is located approximately 7 miles south of NRF. Precipitation data at this station is an approximation for NRF; however, similar physiographic characteristics between the two facilities make the use of these data feasible.

Figures A-5 and A-6 are graphs of monthly and yearly precipitation at CFA since 1972. Each graph demonstrates several interesting trends. Both figures demonstrate the cyclical nature of precipitation over the past 28 years. This pattern persists even in the monthly data graph. Figure A-5 shows another pattern.

The average precipitation in a month is 0.72 inches with an associated standard deviation of 0.6 inches. Occasional monthly precipitation spikes that exceed 1.32 inches (mean and standard deviation) occur. Spikes in Figure A-5 show a consistent pattern of progressive growth then decline. Two such patterns are readily observable between 1976 and 1985, and 1990 and 1996. Both of these intervals roughly correspond to the end of a sustained wetter period.

The amount of precipitation in inches received each year can vary significantly from year to year. For example, in 1988, the precipitation for the year 5.41 inches, or approximately 3 inches below average. The total precipitation in 1995 was 13.38 inches, or approximately 5 inches above average. Between 1988 and 1996, annual precipitation has on average been increasing. Unlike the wet period, which occurred between 1980 and 1986 and was exemplified by a steady rise in yearly precipitation totals, the more recent wet cycle has been very erratic. Beginning in 1988, and lasting until 1997, yearly precipitation totals alternated from lower to higher to lower again. Each alternating year's precipitation averaged higher than two years before. This trend does not appear to continue after 1997. This alternating pattern correlates well with the higher summertime temperatures discussed above. Again, this appears to be evidence of a changing climatic pattern. Currently precipitation amounts seem to be on the decline.

2.2 Climate Conclusions

The data presented in this section show that the climate at the INEEL is highly variable. In a space of 28 years, significant differences in maximum and minimum precipitation and average temperature have occurred. Table A-2 summarizes these extremes. These variations contribute to a complex interaction between climate and hydrology. Over the past 28 years, cyclic variations in temperature and precipitation have occurred. Cyclic variations are more prominent in precipitation data and average wintertime temperature data than average summertime data. The polynomial trend line of the latter is nearly flat. Although the average summertime temperature has been creeping higher, the temperature has remained relatively stable from year to year.

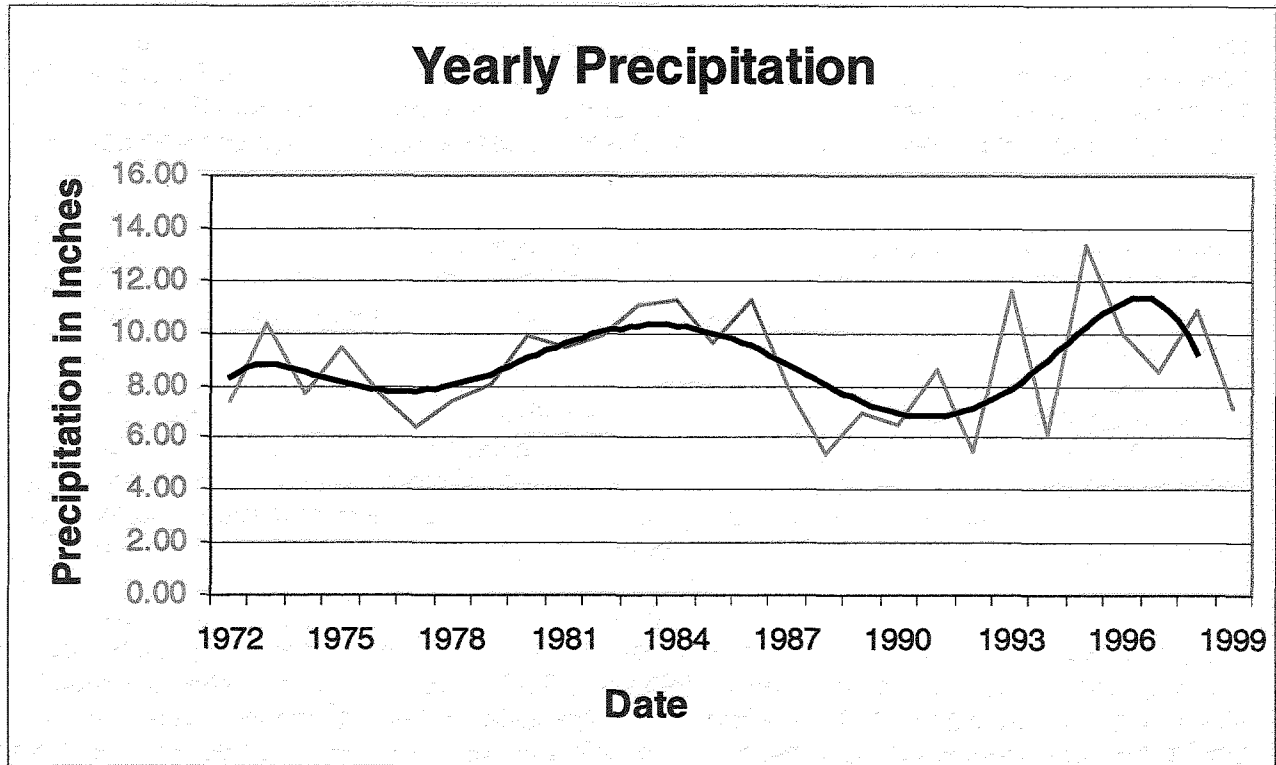


Figure A-5 Yearly Precipitation at CFA

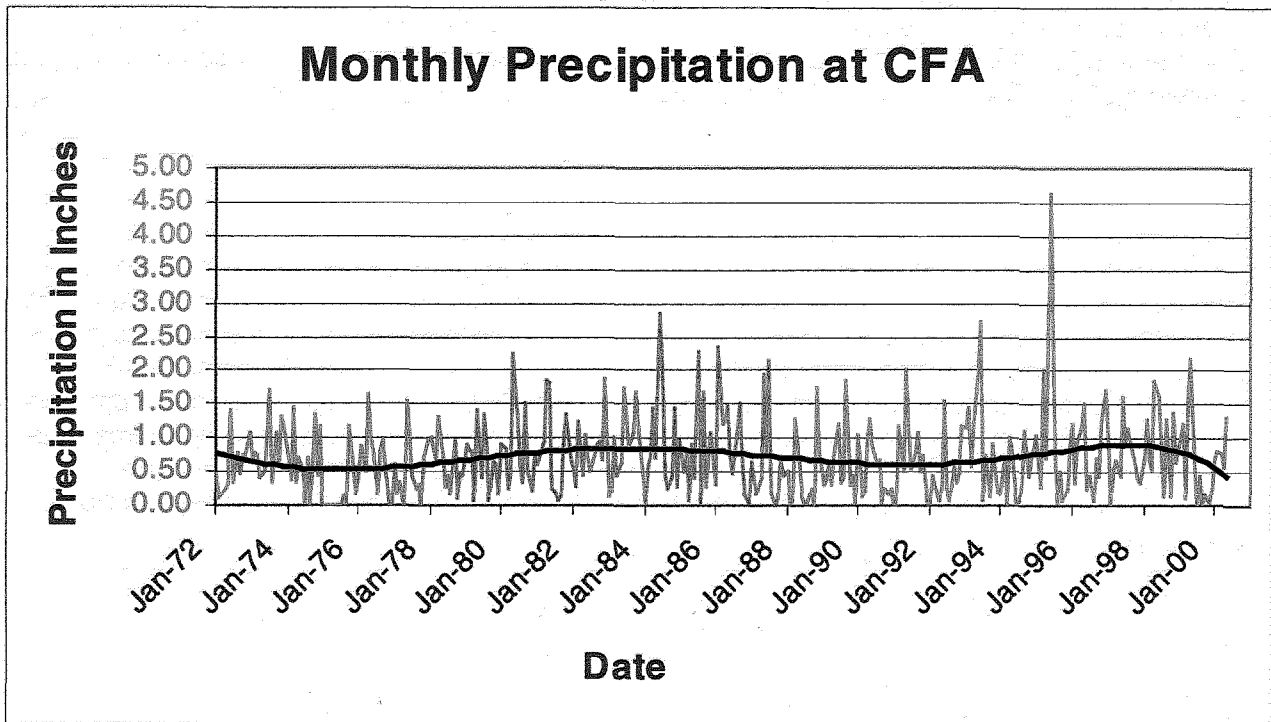


Figure A-6 Monthly Precipitation at CFA

Table A-2 Climatic Variation Summary			
	Summertime Temperature (°F)	Wintertime Temperature (°F)	Precipitation (Inches)
Maximum Average	68.7	25.5	13.38
Minimum Average	58.6	7.9	5.41
Difference	10.1	17.6	7.97

These data indicate that the climate at the INEEL has gone through significant changes over the last 28 years. Most notably, the nineties were more moderate in temperature and wetter than the previous two decades. Furthermore, precipitation events have become more erratic, where the likelihood of a major precipitation event seems to have increased. Temperatures overall appear to be on the rise as well. If current patterns continue, the future climate at the INEEL will produce more rain, promote more infiltration (because of thinner frost layers), and promote continued water flow into the sinks north of NRF. The resulting rise in water table level will have an effect on contaminant migration and groundwater flow paths at NRF. Furthermore, these climate changes may subject NRF to greater risk of flooding from high intensity precipitation events; recent studies place NRF outside the 100-year flood plain.

2.3 Water Table Elevations

Attachment 9 of this document lists water table elevation data for all active groundwater monitoring wells. Hydrographs from USGS-12, USGS-97, USGS-98, and USGS-99 were constructed using data collected from these wells since 1976 (Figure A-7). NRF-6 and NRF-7 reflect water table changes since their construction in 1991. Apart from a few minor differences, the shape of these hydrographs is very similar. The major difference between hydrographs is in the timing of peaks and troughs.

The hydrographs in Figure A-7 show two troughs and one peak for each well. The first trough stretches from 1979 to the first part of 1983, and the second trough occurs between 1993 and 1996. The minimum water table elevations observed in the second trough in all four hydrographs were lower than those observed in the first trough. This represents a continuation of a long term trend of declining water table elevation observed in other INEEL wells (Pittman et.al., 1988) with the extended effect of lowering the water table over the entire Snake River Plain Aquifer. In the case of USGS-99, the difference between the minimum water table elevation in the two troughs was approximately 5.5 feet.

Each of the hydrographs contained one peak that occurred between 1986 and 1988. The difference between maximum and minimum water table elevations in these wells is approximately 16 feet. Both troughs correspond to extended drought periods that occurred during the late 1970s and between 1986 and 1993. The peak followed an extended period that received above-normal precipitation. Currently, the hydrographs are in the process of rebounding; however, in the past several years precipitation amounts have declined. The hydrograph of USGS-12 reflects this change.

Water flux through a particular well and the corresponding water elevation can change rapidly. For example, between May 27, 1982 and May 22, 1984, a space of just under two years, the water elevation in USGS-12 rose 9.38 feet. Between March 26, 1986 and May 7, 1986, a space

of 42 days, the water elevation rose 1.79 feet, or approximately 1/2 inch per day. Finally, in a space of approximately one year, the water table elevation fell 4.29 feet in this well. Well USGS-12 is closest of all NRF groundwater monitoring wells to the Lost River sinks. However, wells located approximately 5 miles downgradient to USGS-12 show similar rapid changes in water table elevations. Such rapid water level changes may cause sudden shifts in groundwater flow patterns around NRF; therefore, caution should be taken when interpreting the results from local monitoring wells, and when estimating aquifer flow paths.

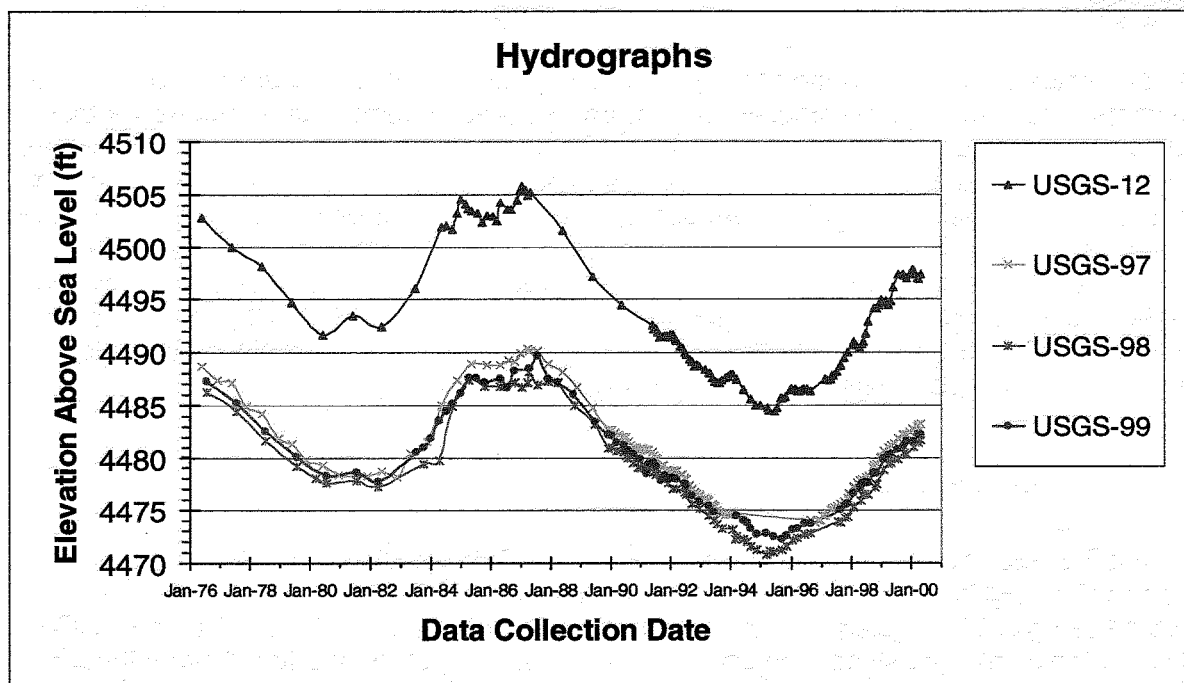


Figure A-7 Selected Hydrographs

It appears that flow to the Lost River sinks contributes large quantities of water for the recharge of the SRPA. The resulting mound beneath the sinks eventually reaches the NRF groundwater monitoring wells and is exhibited as a rise in water table elevation. Because the flow to the sinks is intermittent, water table elevations will rise and fall. The time it takes for peaks and troughs to pass through the NRF groundwater monitoring wells is a function of aquifer hydraulic properties and the quantity of water reaching the aquifer.

When the hydrograph of USGS-12, the most upgradient NRF groundwater monitoring well, is compared to the hydrograph of USGS-99, the most downgradient NRF groundwater monitoring well, the travel time for peaks (and troughs) to pass from USGS-12 to USGS-99 can be estimated. A substantial water table peak occurred at the INEEL during the mid-1980s. In USGS-12, the peak occurred approximately January 26, 1987. This same peak was observed in USGS-99 on approximately July 24, 1987. This is a difference of 176 days. Because of uncertainty associated with the time of collection of water elevation measurements, the peak could have passed through either well sooner or later than the date of the actual measurement discussed above. However, the nearest collection date on either side of peak date sets the limits of uncertainty. Given these constraints, the time of occurrence of the peaks in the two wells could differ by as little as 101 days, or as much as 282 days. USGS-12 and USGS-99 are located approximately 5 miles apart. Based on these numbers, water appears to travel with a

velocity between 94 and 261 feet per day. This velocity is many times greater than published estimates from INEEL sources that range from 5 to 20 feet per day (Robertson, Schoen, and Barraclough, 1973; Robertson and others, 1974). In wells USGS-97 and USGS-98, the peaks occurred in March and July of 1987 respectively, which fall into this same velocity range and support this velocity estimate. Additionally monthly precipitation amounts peaked around September or October of 1986. It took approximately four months (160 days) for the affects to be seen in USGS-12. USGS-12 is located approximately 5 miles south of the Lost Rivers sinks, thus further corroborating the velocity estimate.

Based on the assumption that groundwater flow is in the 5 to 20 feet per day range, then the travel time from USGS-12 to USGS-98 should be 3.6 to 14.5 years, not the 94 to 261 days estimated above. These figures present a dilemma in relation to groundwater flow mechanics. Several hypotheses may explain the differences. These hypotheses are presented in order of likelihood based on the opinion of the author.

The first hypothesis suggests that these high flow velocities are real. Figure A-8 was reproduced from Pittman et. al., 1998, page 17. This map shows the net increase in water table elevation due to flow into the Lost River sinks. Notice that water table elevation increased by approximately 12 feet beneath the sinks, and only seven feet beneath the Central Facilities Area (CFA). The increase was only four feet southwest of the Radioactive Waste Management Complex (RWMC), and at Test Area North (TAN). It was previously shown that rapid rises in water elevation have occurred. Under normal gradient conditions, the hydraulic properties of the SRPA permits flow velocities of 5 to 20 feet per day; however, a rapid rise in water table elevation would cause destabilization of the aquifer, causing the aquifer to seek a new equilibrium state. Since the aquifer is always in flux, this state of equilibrium is never achieved. A higher gradient is temporarily achieved resulting in short term high flow rates. The consequence of such an occurrence would be to create highly variable flow patterns at NRF, and to move larger quantities of aquifer contaminants longer distances in a shorter time span than was previously projected.

A second hypothesis is that the peaks and troughs in the aquifer act as waves rather than a flowing mass of water. In such a situation, water molecules move advectively through the aquifer at a velocity ranging from 5 to 20 feet per day. The wave moves at higher velocities, giving the appearance of higher advective flow velocities. No particular adverse consequence would be rendered to NRF if this is true.

The last hypothesis is that the mechanics of recharge to the aquifer are different than previously thought (Orr and Cecil, 1991). Previously it was accepted that infiltration from precipitation was minimal (Garabedian, 1992), and the largest volume of water entered the aquifer at the Lost River sinks. If direct precipitation infiltration is more significant, and if infiltration along the channel north and east of NRF is more voluminous than previously expected, then the rapid rise in water table elevation observed in the NRF wells could occur. As with the hypothesis above, no particular adverse consequence would be rendered to NRF if this is true.

A comparison of all hydrographs shows a high degree of correlation between each. This correlation indicates that the hydraulic properties of the aquifer are somewhat uniform across the study area, or at least this seems to be true on the macro scale. This assumption is good for assessing large areas or in making generalized conclusions; however, when this assumption is applied to smaller areas, erroneous conclusions may result.

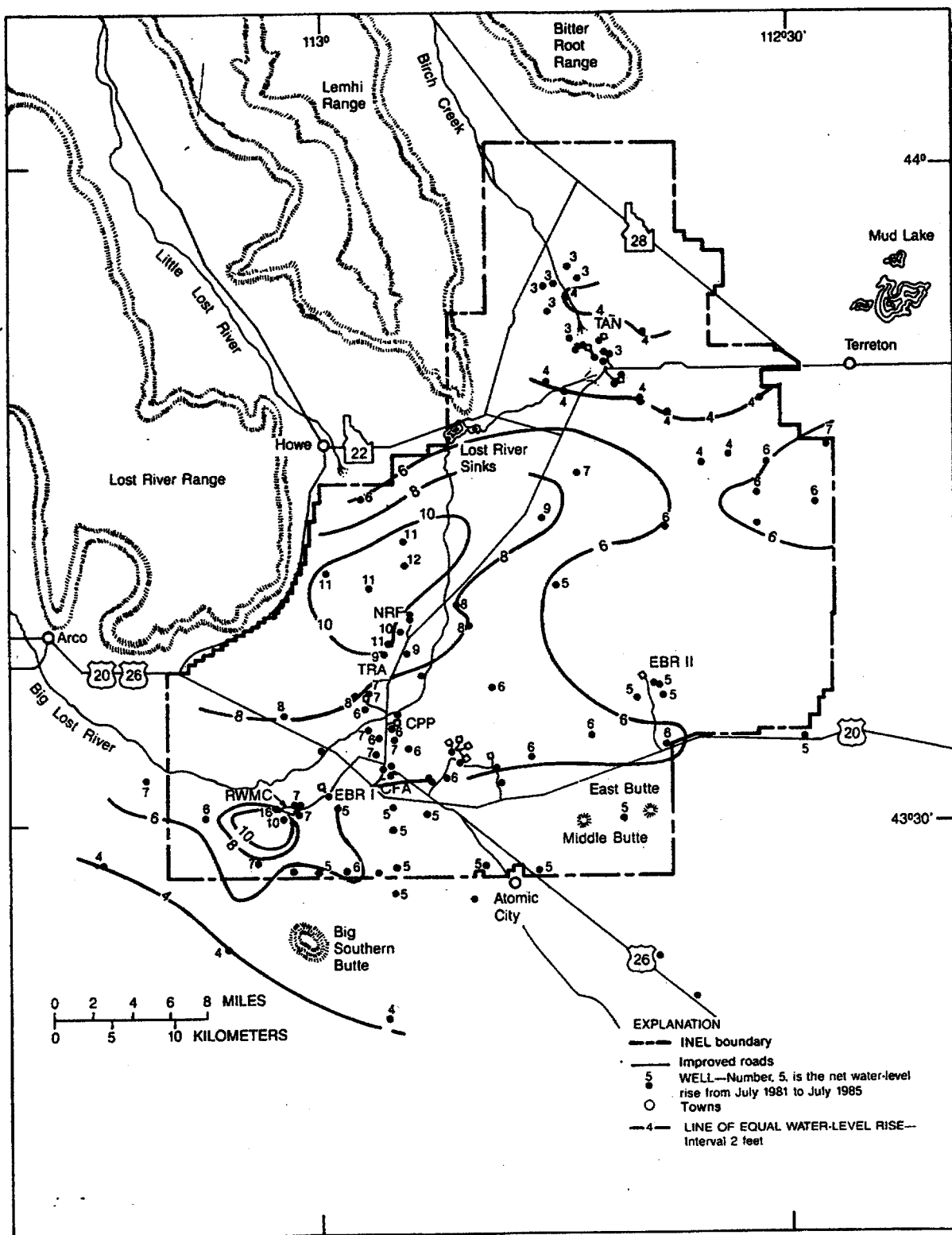


Figure A-8 Generalized Net Rise in Water Table for SRPA, July 1981 to July 1995, after Pittman et. al., 1988

3.0 Long Term Data Analysis

Groundwater quality is affected by many different factors such as the composition of the rock in the aquifer and aquifer source area, climate conditions, and anthropogenic activity. The interactions between these factors are very complex and difficult to predict.

Geology/hydrogeology studies are often limited because the data needed to prove or disprove a hypothesis is often unavailable for direct examination; therefore, circumstantial evidence is often used to infer conclusions. As such, any conclusions must be tempered with a measure of uncertainty.

A single groundwater quality parameter has many factors that influence its value. Changes in groundwater quality can be the result of anthropogenic influences or natural events. This report examines hydrologic and geologic factors that affect groundwater quality. These hydrologic and geologic data are useful as reference sources for other potential environmental issues at NRF. The proper interpretation of these data requires a full understanding of the geologic processes at work specifically at NRF, and at the INEEL in general.

NRF has been collecting groundwater data from 4 of the current 13 groundwater monitoring wells for nearly eight and a half years. Data has been collected for shorter periods from the other wells, depending on their date of construction. Over this period, little in the way of long-term analysis has been done. This section of the report discusses these data from the long-term perspective, since understanding past trends in groundwater constituent concentrations will aid in the prediction of future groundwater concentrations. Included in this section are discussions of both local and regional constituent background levels. The purpose of estimating local NRF background is that the INEEL background estimates, in many instances, are different than local background concentrations. Comparing NRF groundwater data to the INEEL background may lead to erroneous conclusions.

3.1 Background or Upgradient Concentrations for Monitored Constituents

Several studies have been performed that attempt to estimate background concentration levels for various groundwater constituents found at the INEEL (Orr et al, 1991; Knobel et al, 1992; 1999 INEEL Environment Restoration Department Waste Area Group 7 Background Sampling). These estimates are valuable; however, obtaining accurate background information is difficult. Background concentration is affected by both locations of the sampling points and their areal extent. What is considered background for the INEEL may not necessarily be background for NRF. The following paragraphs discuss the complications associated with estimating background concentrations.

The SRPA is complex because there are many source areas for the water that recharges the aquifer. That water follows many flow paths before it reaches the aquifer; geology and hydrogeology of the source area have a significant impact on water characteristics. The Big Lost and Little Lost River systems are major sources of recharge to the SRPA. Each river is supplied by drainage basins that encompass thousands of square miles; however, the Big Lost River system is the larger of the two. The types of rocks in each drainage system are slightly different in both age and composition. Since the basins are of different sizes, the average time that water is in contact with the rocks in the Big Lost River basin is longer than in the Little Lost River basin. Because of the differences between the two basins, each source area imprints its own unique chemistry onto relatively pure rainwater or snowmelt. As recharge water from the

basins reaches the SRPA and becomes subterranean, the rock through which recharge flows further modifies the chemistry of the water. The longer water is in contact with the aquifer host rock, the more its chemistry is modified. All this is further complicated by recharge from the Birch Creek drainage basin, and the Yellowstone Plateau area. These two areas also contribute significant quantities of recharge. The Big Lost River, Little Lost River, and Birch Creek basins contain primarily sedimentary, metasedimentary, and metavolcanic rocks. The Yellowstone Plateau consists of recent volcanic rocks. Two additional significant sources of recharge to the SRPA near INEEL further complicate the determination of background concentration; these sources are direct infiltration from precipitation, and the Lost River Sinks located in the northwest portion of the INEEL.

Although some studies (Garabedien, 1992; Environmental Restoration Department Waste Area Group 7, 1999) indicate that direct infiltration into the aquifer is not a significant source of recharge to the SRPA on a large scale, they do show that direct recharge is significant on a local scale. Localized direct aquifer recharge is enhanced by small closed depressions in the ground surface, and very porous surface materials such as fractured basalt. At the INEEL, the areal distribution of localized direct recharge is essentially random and is controlled from year to year by the amount of rain and snow, and by temperature patterns. The random distribution of aquifer recharge adds uncertainty to any efforts to statistically estimate background concentrations.

Infiltration at the Lost River Sinks contributes a large amount of uncertainty to the determination of background concentrations in the SRPA. When water flow volumes in the Big and Little Lost River systems are considerable, channel flow will reach the Lost River Sinks. Over time, a large shallow lake forms, which facilitates the infiltration of large quantities of water to the aquifer. Since the flow path for this water is different from the subterranean flow in the aquifer, the chemistry of the groundwater in the SRPA at the recharge point is affected. As flow to the sinks ceases, the chemistry of the SRPA at the recharge point reverts to pre-flow conditions. This hydrogeological process creates a dynamic system that constantly affects SRPA groundwater geochemistry.

The difficulty in estimating background concentrations is how to interpret the data. Sampling will yield different results depending upon location (spatial variability) and time of year (temporal variability), and yet this variability is all naturally occurring. Between spatial and temporal variability, and normal laboratory-induced data variability, a large number of samples must be collected over a long time period to establish a reasonable "background range". The problem with this approach is cost. The number of wells needed to accurately sample a large area is usually very expensive. Furthermore, the cost of sampling these wells over many years and analyzing for many constituents is likewise high. In most cases at the INEEL, background values are available based on only one or two rounds of sampling from a relatively few well locations.

In this report, two background terms are presented. One is regional or INEEL background, and the other is local background. INEEL background is subject to all the limitations described above. Reducing the area of interest produces local background estimations. In the past, INEEL background concentrations have been compared to the concentrations found in NRF groundwater monitoring wells to determine if NRF operations have adversely impacted the SRPA near the facility. However, INEEL background concentrations may not accurately reflect water quality directly upgradient to NRF for the reasons described above. This report therefore emphasizes establishing local background values, for more meaningful comparison with site data. Since data collection is an ongoing process, it is expected that local background values

will continue to be refined in the future. Several difficulties were encountered in determining local constituent background concentrations and are discussed below.

NRF has two wells in the monitoring network that are believed to sample background or upgradient groundwater constituent concentrations. These wells are USGS-12 and NRF-7. Both wells have problems that limit their usefulness as background monitoring wells. These problems are documented in the NRF Comprehensive Remedial Investigation and Feasibility Study (WEC, 1997), and include multiple completion levels, improper well grouting, and carbon steel in contact with aquifer water. However, these wells supply valuable information to the NRF groundwater monitoring program, and are the most logical choices for local upgradient constituent concentrations in the absence of costly additional well drilling. Local background concentrations will therefore be estimated using data from USGS-12 and NRF-7.

Data has been collected from USGS-12 since 1989 and from NRF-7 since 1995. Attachment 1 summarizes the average concentrations (with associated standard deviations) for all constituents currently monitored by NRF at USGS-12 and NRF-7. These concentrations are estimates of background since they are derived, for the most part, from a single well. Additionally, the Method Detection Limits (MDLs) for the constituents of concern have changed over time because several different analytical laboratories have been used to perform data analysis. In some cases, the MDL is an order of magnitude different between laboratories. To mitigate the affects of widely varying MDL values, some data values were not used in calculating the estimated constituent background concentration. Using elevated MDLs would bias results to the high side, thus masking the presence and nature of potential groundwater contaminants.

Trend analysis shows that concentrations for the various constituents are changing over time in USGS-12. It is expected that they will continue to change in the future, thus affecting the estimate for background concentration. As time passes, it is anticipated that more data from NRF-7 will be used in calculating background concentrations.

Based on data in Attachment 1, and other INEEL and NRF geologic documents, it appears that beryllium, cadmium, copper, lead, mercury, silver, thallium, zinc, nitrite (NO₂), and total Kjeldahl nitrogen (TKN) do not occur naturally in the aquifer, or they occur at levels consistently below the MDLs. The average of six other constituents (aluminum, arsenic, calcium, magnesium, nickel, and selenium) from USGS-12 and NRF-7 that do occur naturally are below the levels occurring in any other NRF groundwater monitoring wells. The remaining constituent concentrations are sometimes higher and sometimes lower than concentrations found in the remaining wells.

Local background levels for radiological parameters appear to be relatively low and in some cases near zero. Strontium-90 and cesium-137 have backgrounds of 0.29 and 0.02 pCi/L, but range from 0 to 0.95 pCi/L and 0 to 0.87 pCi/L, respectively. Background for tritium is 28 pCi/L with a two standard deviation range (2s) of 9 to 47 pCi/L. Two other parameters, gross alpha and gross beta, have 2s ranges of 1.28 to 2.64 pCi/L and 2.83 to 4.63 pCi/L, respectively. Table A-3 compares various regional estimates of background to local estimates. With one possible exception, all NRF local background activity levels are lower than the other estimated background activity levels. The one possible exception is for Sr-90 samples collected near the INEEL in 1989 (samples collected outside the boundary of the INEEL), which show a range of 0.02 to 0.12 pCi/L. This range falls within the NRF local background range, but is less than the upper level (0.34 pCi/L). In comparison to NRF, INEEL numbers for tritium are quite high. This

is due solely to the results of several wells near contaminated INEEL facilities and demonstrates the need for deriving local background levels for tritium.

	Gross α	Gross β	Cs-137 ^a	Sr-90 ^c	Tritium
NRF-Local	1.96±0.68	3.73±0.90	0.02±0.85	0.29±0.66	28±19
1981 Public Water	2.6±0.5	3.6±0.5	No Data	No Data	No Data
IDAHO in General	0 to 5	0 to 8	Near Zero	Near Zero	75 to 150
1989 NEAR INEEL	4.4±0.90	8.4±1.1	No Data	0.07±0.05	42±9
1988 INEEL	2.7±0.30	5.1±0.7	7.7±3.9 ^b	5.0±1.7 ^d	8190±2080 ^e
1999 INEEL	2.77±0.99	5.80±0.79	1.02±0.81	No Data	959±174 ^e
Federal MCL	15.0	4 mrem/yr	NA	8.0	20,000

- a Cesium 137 does not occur naturally, but is a fission product from nuclear facilities and also occurs due to fallout from atmospheric weapons tests
- b Samples collected during 1987 from 48 wells at the INEL (Knobel and Mann, 1988)
- c Strontium occurs naturally in very limited quantities in uranium enriched deposits.
- d October 1988
- e This value included results from wells that were clearly influenced by INEL facilities' releases; i.e., maximum results of 80,600 pCi/L.

Data from NRF-7 and USGS-12 generally support the conclusion that for most constituents, concentration levels observed in these wells can be appropriately used as background levels for the NRF site. Some confusion arises in cases where concentrations for certain constituents are higher in water samples from the background wells than concentrations occurring in downgradient wells (i.e., barium, chromium, iron, manganese, potassium, sodium, chloride, sulfate, nitrate, and phosphorus.). This may be due to one of two causes. The first cause is related to random statistical variations in natural background concentrations as discussed previously. This is probably what is occurring in the NRF groundwater monitoring network. The other possibility is that the water quality at NRF-7 and USGS-12 is being affected by processes upgradient of the wells which add constituents to the aquifer. Natural attenuation processes such as dispersion and/or degradation could reduce the concentration of these constituents before they reach the other wells located near NRF. This possibility is not supported by any direct evidence.

3.2 Long Term Trend Analysis

One purpose for collecting groundwater monitoring data is to assess systematic changes in groundwater constituent concentrations over time (trend analysis). Trends may be short term, long term, subtle, complex, or obvious. Trend analysis can be performed using several methods. Straightforward examination of graphs reveals the obvious trends. In more complex cases, numerical trend analysis may be required. Many spreadsheets and statistical programs contain numerical trend analysis functions. The spreadsheet or statistical program superimposes a best-fit line onto the graph in question. This line indicates possible short- or long-term trends existing in the data. For the purposes of this report, a long-term trend is defined as a consistent change in data that can be tracked over a period of approximately five or more years. These are sometimes referred to as "macro-trends". "Micro-trends" or "sub-trends" are generally measured in terms of months. Patterns may be part of macro-trends

or sub-trends, but are usually repeated shapes in data graphs that identify similar underlying causes.

One of the best yet simplest ways of analyzing trends is the graphical method. Data collected over long periods of time can be analyzed quickly. NRF has collected data for many different constituents since 1989. NRF currently analyzes groundwater for 29 inorganic and nutrient constituents, 5 radiological parameters, and 26 volatile and semi-volatile organic constituents. Because of the large number of constituents analyzed, it is not practical to discuss all of them in detail; however, several constituents appear to be good indicators of groundwater quality trends. These constituents are chromium, calcium, chloride, and tritium. Chromium was released historically in quantity at many locations on NRF. Chromium will persist in the environment over time and is the primary non-radiological constituent of concern at NRF. Calcium is a naturally occurring constituent that reflects changes in natural hydrologic processes. Chloride is released in quantity at NRF in the form of salt (e.g., for water softening). Chloride is also very persistent in the environment; therefore, it can be used to trace the movement of water in the aquifer. Tritium was released to the environment in quantity in the past at two NRF locations. The movement of tritium in the environment is not retarded by the material through which it travels since tritium is present in the form of water; hence, tritium is also an excellent indicator of water flow paths.

Groundwater data were graphed and analyzed for trends. In many cases, a straight line can approximate trends. These lines can slope up, slope down, or be flat. This simple modeling works well for some of the NRF data; however, some of the data display split trends. In these cases, polynomial trend lines may be used, or the graph can be broken into shorter segments manually. This section presents graphical data and assessments of the data. The analytical results for groundwater samples collected from active wells since 1989 are shown in Attachment 2, which lists the average concentration and associated standard deviation for each constituent. The maximum and minimum values over that period for each constituent are shown as well.

3.2.1 Aquifer Chromium

Chromium is a naturally occurring constituent in groundwater. At the INEEL, background chromium concentrations typically range from 2 to 3 ppb. Past hydrogeological investigations established that historic NRF practices increased chromium concentrations in the groundwater. These investigations also demonstrated that the sediments beneath the IWD are the primary source for chromium being released to the SRPA at NRF, since NRF now only releases trace quantities in its effluent. The quantity of chromium being released to the SRPA is related to the volume of water being flushed through the sediments in the IWD. In recent years, downsizing at NRF has reduced the volume of water released to the IWD. This reduction is now being reflected in reduced downgradient groundwater constituent concentrations (e.g., for chromium).

Attachment 3 provides individual graphs for each well. NRF-6 and NRF-12 are the only wells that demonstrate little or no variation in chromium concentration since their construction. A two-quarter spike that occurred during January and June of 1997 can be seen as a prominent feature on both figures. In both instances, the peak concentration was seven to eight times higher than the average concentration. This and similar spikes may be the result of erroneous data, or it may represent a true aquifer condition. There are many mechanisms that can cause these spikes. One of the more likely mechanisms is an anomalous release of chromium from the sediments of the IWD that quickly migrated to the wells in question. Constituent migration

then continued downgradient. This mechanism required that a variation in IWD water chemistry initiate the release. Furthermore, this mechanism assumes that the concentration of chromium along all migration paths from the IWD is the same before and after the release. A second likely mechanism suggests that chromium concentrations across different migration paths are not the same. The aquifer beneath the IWD contains a complex distribution of chromium in the groundwater resembling fingers. As migration paths shift over time as a result of changing aquifer conditions, water containing different chromium concentrations intersects the wells. Since this mechanism is dynamic by nature, spikes will occur abruptly and then disappear. A combination of both mechanisms is also possible.

Spikes similar to those seen for NRF-6 and 12 are also observed in the graphs of data for the other wells, particularly USGS-99 in January 1997. These spikes are generally smaller than the two that occurred in NRF-6 and NRF-12, and in many cases are represented by only one data point. Historically, such spikes were considered to be anomalous occurrences and not indicative of hydrogeologic mechanisms; however, they may represent "real" data, especially if the second mechanism discussed above is correct. Note that the low groundwater velocity present in the SRPA at NRF does not support the first mechanism above, since a peak at NRF-6 and NRF-12 would not be expected to correspond to a simultaneous peak at USGS-99.

NRF-6 and NRF-12 are the two wells that are the hydrologically closest to the outfall of the IWD in the downgradient direction. The continued presence of chromium in these wells probably reflects persistent leaching of chromium from sediments located beneath the IWD. Figure A-1 shows the location of these wells.

The graphs of both NRF-8 and NRF-13 show a long term increasing trend. In both instances the trend is made primarily due to the results of the last three or four quarters. Prior to these data, the trends were neutral or slightly decreasing. The cause for recent rises in concentrations are probably related to changes in groundwater flow patterns beneath NRF resulting from decreases in effluent discharge to the IWD, and discontinued flow in the Big Lost River.

A long-term trend seen as declining chromium concentrations is present in the graphs of data from 8 of 13 NRF wells. However, in only two wells (NRF-9 and NRF-10) has this decline been continuous over the life of the wells. NRF-11 demonstrates a long-term decline in chromium after the first several quarters of data. The remaining wells (USGS-12, 97, 98, 99, and USGS-102) have shown a steady decline in chromium concentration up until the past 7 sampling quarters. Chromium concentrations in these wells have risen 2 and 4 ppb over the past seven quarters. All the groups discussed above are based on general observations and represent a macro view of the trends contained in the data.

As discussed earlier, sub-trends are commonly present in the Attachment 3 graphs of the well data. USGS-102 is a good example of the macro (general) and sub-trends contained in the same graph. The best-fit line drawn through the data points from USGS-102 begins at approximately 7.5 ppb and ends at 6.1 ppb. This is the macro trend. This graph, like the others, shows a high degree of variability. There are at least three repetitions of a sub-trend imbedded within the macro-trend. These sub-trends are characterized by at least seven data points each showing a large sudden decline followed by a two year increasing trend followed by another sudden drop. The cause of this pattern is not fully known, but it may be related to variations in aquifer flow patterns.

The graph of NRF-7 data does not clearly fit in any of the groups discussed above. The chromium concentration in this well could be viewed as rising from approximately 10 ppb in 1991 to approximately 15 ppb in 1996. By mid-1997, the concentration of chromium in this well again fell to 10 ppb, and has risen only slightly since then.

Figure A-9 shows the results of all data when placed on the same graph, except NRF-6 and NRF-12 contained spikes in 1997 that are not shown on the graph. The validity of the spike data is uncertain. The concentration of chromium in NRF-6 and NRF-13 is clearly the highest. These wells are near the IWD. NRF-6 is hydrologically affected by effluent discharge to the IWD, while NRF-13 could also be affected. NRF-13 contains a high level of suspended solids. Chromium is a possible constituent in the suspended solid; therefore, water samples from this well could reasonably be expected to produce high results for chromium. Filtering samples from this well might show reduced chromium content.

The NRF-11 graph begins higher than the graph of NRF-12, but the latter finishes higher. Both NRF-11 and NRF-12 are located hydrologically downgradient of NRF-6. This figure confirms that as the wells become hydrologically further downgradient, the chromium levels in the wells drop. This is to be expected, as the IWD is believed to be the main source for chromium to the SRPA. This figure also shows a group of wells clustered near the bottom of the graph. These wells are tracking at or near local background concentrations.

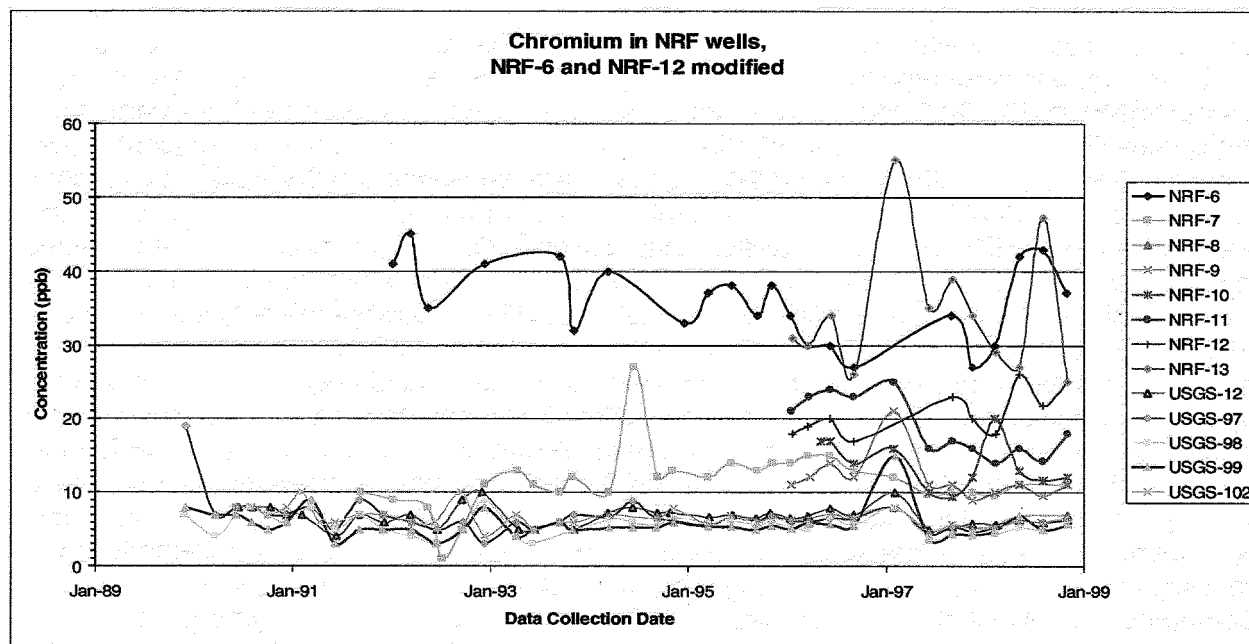


Figure A-9 Chromium in NRF wells, omitting Spikes in NRF-6 and NRF-12

3.2.2 Aquifer Chloride

Effluent released to the IWD has routinely contained chloride ions. Ionic chloride is also a common, naturally occurring constituent in groundwater. At the INEEL, background chloride concentrations typically range from 5000 to 15000 ppb. Chloride ions are good tracer constituents since they are relatively unaffected by common retardation mechanisms associated with the aquifer system. This property allows flow path analysis to be performed as well as

estimation of the size and areal distribution of associated contaminant plumes. When graphs of chloride data were examined (Attachment 4), the following results were observed.

When examined on a macro scale, graphs of chloride concentration can be divided into three groups. Wells that show a decreasing trend (NRF-7, NRF-12, USGS-12 and USGS-98); wells that show no particular trend (NRF-9 and USGS-99); and wells that show an increasing trend (NRF-6, NRF-8, NRF-10, NRF-11, NRF-13, USGS-97, and USGS-102).

Several sub-trends are imbedded within the main trend observed in NRF-7. For example, chloride concentrations in NRF-7 exhibit a stair-step pattern of decline. This pattern is characterized by a slow increase, followed by a rapid decline, followed once again by a slow rise in concentration. This pattern repeats itself four times in NRF-7. Since 1998, the concentration in NRF-7 has risen 2000 ppb, or 45%; however, since 1991, the overall chloride concentrations in NRF-7 have declined 14%. NRF-12 and USGS-12 also possess long term downward trends, representing an 8% and 23% decline in concentration since 1996 and 1991, respectively.

Both NRF-12 and USGS-12 also possess strong downward trends over the past 7 to 12 quarters. Over this time span, the concentrations have declined by 15,000 ppb (63%) and 25,000 ppb (23%), respectively. On the other hand, the chloride concentration in USGS-98 has fallen approximately 2000 ppb, or 13%, since 1989. The graph of USGS-98 is characterized by strong fluctuations through the first quarter of 1994, after which the fluctuations nearly stop.

USGS-12 is hydrologically upgradient to NRF; therefore, this well is the primary source for upgradient groundwater monitoring information. Up until the first quarter of 1997, the chloride concentration in USGS-12 was trending upwards. Beginning in February 1997, a steady but precipitous decline in chloride concentration occurred. Similar declines may be present in the graphs of NRF-6 and NRF-12 data, indicating that the water from the sinks is just now reaching these wells. USGS-12 is located approximately 3 miles north (upgradient) of NRF and should not be affected by NRF or INEEL activities; thus, the chloride concentration would be expected to remain relatively constant over time. Several possibilities exist why these unexpected results are being observed. USGS-12, although upgradient to NRF, is downgradient to the Little Lost River drainage system. The Little Lost River valley is used for ranching and agricultural purposes. Contaminants entering the groundwater could have an effect on water quality in USGS-12. Additionally, recent changes in precipitation patterns have caused a persistent flow in the Big Lost River past the INEEL diversion dam. A groundwater modeling study performed in conjunction with the NRF Comprehensive RI/FS concluded that during wetter periods, flow in the Big Lost River, and the resulting increased percolation at the Big Lost River sinks, resulted in a mounding of water in the aquifer northwest NRF. Empirical data supports this modeling conclusion. The results of this mounding are likely twofold. First, as postulated in the NRF Comprehensive RI/FS, flow direction in the SRPA near NRF is forced to assume a more southwestern direction. The other potential consequence is dilution of aquifer constituents causing an apparent decline in chloride concentration. Chloride concentrations in USGS-12 have ranged from 33,000 to approximately 40,000 ppb, but most recently it was approximately 20,000 ppb.

The pattern of decline exhibited by these wells provides limited information about the hydrology at NRF. The graph of NRF-7 is of particular interest. This well is within 750 feet of the IWD; however, chloride concentrations in this well have been historically low. This lends credence to the postulate that water in this well represents upgradient conditions. The fact that the chloride concentrations in both NRF-6 and NRF-13 are rising suggests that a groundwater barrier may

exist between the IWD and areas to the north (i.e., USGS-12) and east (i.e., NRF-7). Such a barrier would be a significant factor in controlling the flow of groundwater near NRF.

Two wells (NRF-9 and USGS-99) display a neutral trend in concentration. The graph of USGS-99 data in general appearance looks very similar to the graph of USGS-98 data, although the average concentrations are different.

Figures A-10 and A-11 are composite graphs of chloride data from the NRF monitoring wells. The first graph includes the data collected from NRF-6. This well is near the IWD; therefore, it contains high levels of salts reflecting the contents of the effluent discharged to the IWD. Figure A-10 is dominated by the presence of the NRF-6 data. When the data from NRF-6 are removed, the results shown in Figure A-11 are obtained. This graph clearly shows the separation in chloride concentration from well to well. Furthermore, the data from both graphs form four groups based on concentration. The first group, which possesses that highest average concentration of chloride, contains wells NRF-6, NRF-12, and NRF-13. Not surprisingly, these three wells are hydrologically nearest the IWD. The group with the next lower average concentration contains wells NRF-9, NRF-10, and NRF-11. NRF-9 through NRF-11 are progressively further hydrologically from the IWD than the wells in the first group. The third group contains wells NRF-8, USGS-12, USGS-97, and USGS-102. These four wells are either background or hydrologically distant from the IWD. The most significant observation related to this graph is what has happened to the concentration of chloride in USGS-12 since approximately the beginning of 1997. The concentrations in this well were tracking almost exactly those of NRF-8, USGS-97, and USGS-102 (where all wells show an upward trend), then its concentration has declined both significantly and rapidly since. The concentration in USGS-12 now matches that of USGS-98. This decline began about the same time that the hydrograph (discussed later) for this well began to rise. This indicates that fresher water from the Big Lost River is diluting more chloride-rich water in the aquifer. This effect is expected to be seen in other NRF wells in the future. The last group contains wells NRF-7, USGS-98, and USGS-99. These wells are all background or hydrologically distant from the IWD. Overall, the distribution of the wells on this graph reflects that the IWD is the major chloride contributor to the aquifer near NRF.

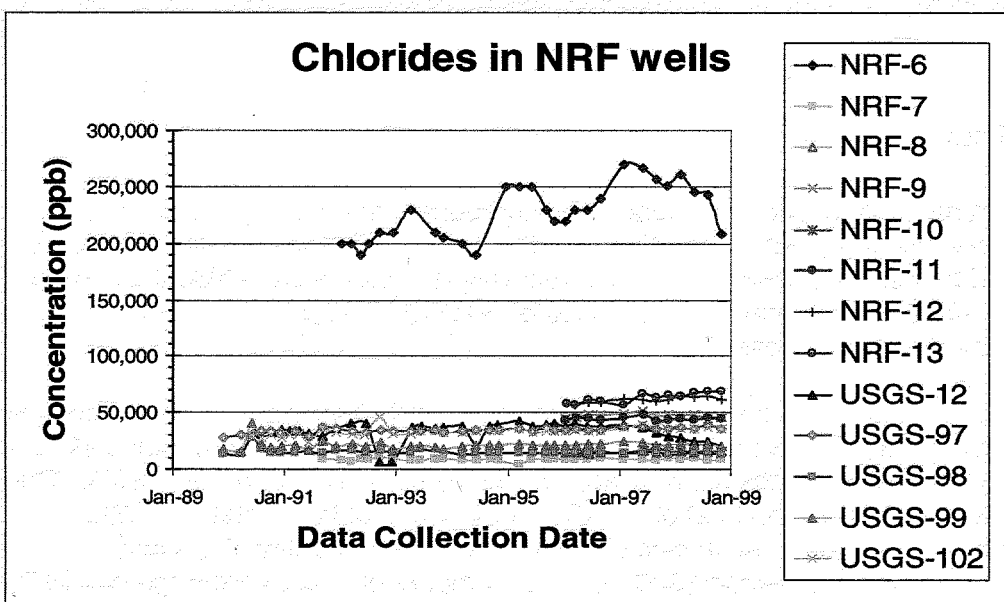


Figure A-10 Chlorides in NRF Wells

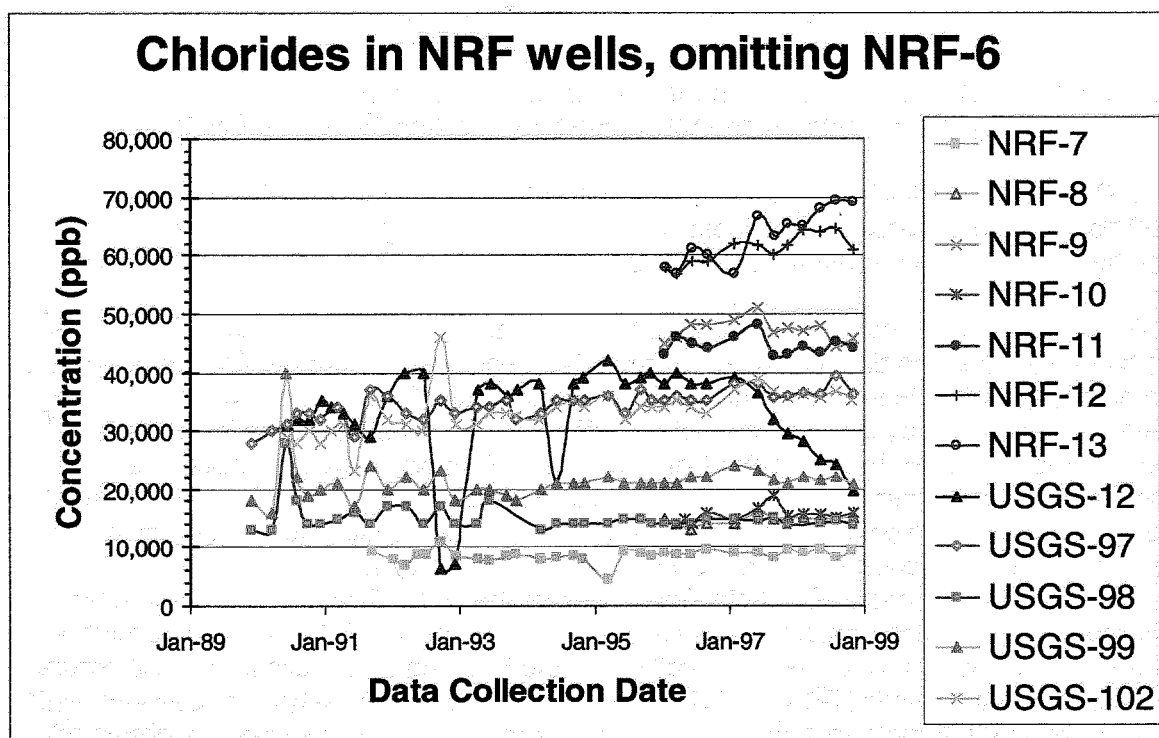


Figure A-11 Chlorides in NRF Wells, Omitting NRF-6

Another noteworthy observation is the similarity between the shapes of the graphs of data collected from wells NRF-8 through NRF-11. The significance of this is their proximity to the IWD. These graphs all show that chloride concentration has risen and then fallen since 1995. The chloride concentration in these graphs also indicates a peak at nearly the same point in time. The shape of the graphs from NRF-9 and NRF-10 are very similar. The same is true of the graphs of NRF-8 and NRF-11. Prior to adding the last several quarters of data, the prevailing trends were opposite for each pair. With the addition of the new data, the trends are tending toward synchronization. These observations highlight the possibility that trends in these wells are under-developed, such that insufficient time has passed for the true trends to manifest themselves.

3.2.3 Aquifer Calcium

Calcium is a common naturally-occurring groundwater component that strongly reflects the source of the water in which it resides. The effluent to the IWD and the sewage lagoon are not specifically monitored for calcium; however, results from NRF-6 indicate that effluent discharged to the IWD from NRF does contain enriched quantities of calcium. The primary source of calcium is from water softening processes.

Attachment 6 presents calcium concentration graphs for each well. The graph of NRF-7 data is the only one that demonstrates a clear trend of increasing calcium concentration. Since 1996, it appears that calcium concentration has risen by approximately 5,500 ppb or roughly 23%. The water quality in this well is typically the best of all NRF wells. Several facts related to IWD discharge may explain the apparent rise in calcium in this well. The quantity of effluent discharged to the IWD has declined since 1996. Both the amount of aquifer recharge due to the IWD and the distance that water flows in the channel has decreased. These two factors may

have fundamentally altered the hydrologic balance in the aquifer resulting in the possible infusion of IWD water or other upgradient, but higher concentration, water to the NRF-7 well. The infusion of IWD water to NRF-7 is probably not as likely based on the chromium and chloride data confirming the validity of NRF-7 being an appropriate background well, and suggesting that no influence from the IWD appears responsible for this trend; therefore, natural causes (upgradient water) probably related to groundwater flow changes are suspected. This same trend is observed in data of other ionic constituents such as magnesium and sodium.

The graph of NRF-11 and NRF-13 data are difficult to interpret, as they do not show strong trends; however, in basic appearance, these graphs do show a potential slight upward trend. Both wells are in the proximity of the IWD, and may be influenced by it.

The graphs of NRF-6, NRF-10, and USGS-12 all show strong downward trends. The calcium concentrations in these wells declined approximately 40,000 ppb (30%), 6,000 ppb (10%), and 14,000 ppb (20%), respectively. The decline depicted in the graph of USGS-12 data is most prominent. Almost certainly, this decline was precipitated by a period of extended flow in the Big Lost River channel. Relatively calcium-poor river water was diluting the higher concentrations of calcium found in the aquifer. Concentrations in NRF-6 are dropping rapidly, especially since January 1997. The reason for this drop is probably related to a corresponding drop in domestic water use at NRF. As domestic water use drops so does the need for softened water, thus a decrease in calcium discharges to the IWD. The trend observed in NRF-10 may be best explained in the discussion concerning the remaining wells.

The remaining NRF wells, which include NRF-8, NRF-9, NRF-12, USGS-97, USGS-98, USGS-99, and USGS-102, all display compound trends. In most of these wells, the calcium concentration has been sharply falling since 1997. If only the period from mid-1995 to the beginning of 1999 is examined, then an upward trend is observed in the graphs of these same wells. With the exception of one data point collected during 1995 from NRF-10, the same up then down trend can be seen in the graph of this well. The downward trends observed in all these wells is best explained by the dilution affect discussed above; however, the difference between the beginning of the drop in concentration between USGS-12, the upgradient well, and the rest of the wells, is explained by the distance between the wells; it takes time for water to travel the approximately 3 miles between USGS-12 and NRF. As the water arrives, the influx of fresher water lowers the average calcium concentrations in these wells.

3.2.4 Aquifer Tritium

Tritium releases to the environment were discussed in the NRF Comprehensive RI/FS. The geologic evidence presented in that document suggests that an active source of tritium exists beneath the historical location of the S1W Leaching Beds. The following discussion addresses long-term trends observed in tritium groundwater concentrations.

Tritium occurs naturally in groundwater, but at low concentrations. This is particularly so prior to 1945. Above ground nuclear testing after 1945 has elevated groundwater tritium concentration worldwide. This phenomenon is observable in the groundwater beneath the INEEL. Tritium background at the INEEL has been estimated by the United State Geological Survey to be between 75 and 150 pCi/L. In comparison to NRF wells, these values are high. Results from NRF monitoring indicates that background for NRF is somewhere between zero and 60 pCi/L. This is the range of values associated with one standard deviation around the mean (i.e., 28 ± 32).

Anthropogenic tritium has two primary sources, reactors and nuclear bombs. Above ground nuclear testing has all but ceased worldwide, and the free release of tritium-enriched water to the environment is no longer practiced at NRF (since 1978 (WEC 1997)) or the INEEL (1986 (Seihlke, 2000)). Add decay to the equation (tritium has a half-life of approximately 12.3 years) and groundwater tritium concentrations should be declining; however, the opposite is observed in some cases at NRF and the INEEL. Increasing groundwater tritium in the NRF wells may be from: 1) An unknown upgradient source; 2) Old fallout-affected water that is only now reaching the monitoring wells; 3) Hydrological factors related to changes in local recharge patterns; or, 4) Natural statistical trends in groundwater. Future NRF and INEEL data may narrow the choices or present new choices.

Attachment 5 provides tritium concentration graphs for each well. Tritium concentrations demonstrate an apparent upward trend in NRF-7, NRF-8, NRF-12, NRF-13, USGS-12, and USGS-102. The corresponding increase in each well over the sampling duration is approximately 20(-10 to 10), 11 (24%), 5 (10%), 10 (27%), 20 (40%), and 7 (13%) pCi/L, respectively. The upward nature of the trends in all the graphs except for USGS-12 exhibit highly variable tritium concentrations from quarter to quarter, which tends to mask the underlying trends and makes interpretation more difficult. The trend seen in USGS-12 has been more persistent. The fact that both NRF upgradient wells show an increasing trend makes an interpretation of tritium data more difficult, since the logical expectation was that tritium concentrations in these wells should be falling as discussed above.

The overall trend for NRF-6 and USGS-99 is essentially neutral; however, for the past two years, concentrations appear to be falling.

The tritium concentration in five wells shows a strong downward trend. These wells are NRF- 9 through NRF-11, USGS-97, and USGS-98. The most dramatic decline in concentration occurred in NRF-9 and NRF-11. Concentrations in these two wells has fallen approximately 60 (45%) pCi/L and 220 (68%) pCi/L, respectively. The magnitude of decline in the other wells ranges from 5 to 25 pCi/L.

Graphs of tritium concentration from the three wells included in the Regional Downgradient group (USGS-97 to USGS-99) demonstrate a consistent pattern. Each graph displays a high degree of variability. This variability may reflect changing flow paths within the aquifer or they may be random statistical fluctuations (e.g., analysis bias across all sample points for a given time period, or variations within a sample set related to measurement techniques).

Declining tritium concentrations in the aquifer near NRF may be attributed to radiological decay, dilution, source depletion, or dispersion. Each mechanism is discussed below.

Decay is a mechanism that explains about 15% of the apparent decline in groundwater tritium concentrations. It follows that this mechanism is secondary to other possible mechanisms.

Apparent declines in tritium concentration over time may be partially or wholly explained by the effects of dilution. Over the past several years, water flow within the channel of the Big Lost River has been nearly continuous. Over the vast majority of this time, water has reached the sinks located north and upgradient of NRF. Over this same period, the water level in the NRF wells has been rising, indicating that the recharge from the sinks is reaching NRF. Increased flow volume in the aquifer beneath NRF could cause tritium concentrations to decline due to the affects of dilution.

The bulk of tritium now found in the NRF groundwater monitoring wells was probably discharged to the S1W leaching beds approximately 35 years ago, when tritium was last discharged. Past studies at the INEEL indicate that unimpeded migration of water from the surface to the aquifer behind substantial driving head takes 3 to 6 months. Since elevated levels of tritium are present in NRF groundwater, a mechanism that impedes the free migration of water must be present. The most probable impediment is a semi-permeable sedimentary layer. Tritium recently observed in the aquifer probably has, as its origin, a residual perched water zone located beneath the S1W leaching beds on top of the sedimentary layer. Depletion of this perched water zone, and the accompanying decline in water volume released to the aquifer, is likely at least partially responsible for the observed decline in aquifer tritium concentrations.

Dispersion may also contribute to the apparent decline in tritium concentration in the groundwater monitoring wells. Dispersion is a term that is often confused with dilution. Both mechanisms may be active in the aquifer beneath NRF. As used in this document, dilution is associated with a rise in aquifer level and an increase in flow volume; the mixing of uncontaminated water with tritiated water decreases the overall tritium concentration in the water. Conversely, dispersion is the mechanical mixing of contaminant-laden water with 'clean' water due to differential flow path lengths and advective groundwater flow. Unlike dilution, no change in aquifer water flux is needed to cause a drop in constituent concentration.

Dispersion in the aquifer occurs in microscopic pore spaces as well as in macroscopic fractures. The physical properties of the aquifer are seldom isotropic (i.e., exhibiting the same physical properties in all directions). If the flow direction in the aquifer changes, then the magnitude of dispersion will be different. Differential dispersion will be reflected in the wells as a gradual change in groundwater constituent concentration over time.

Figure A-12 is a composite graph of all tritium data from all NRF groundwater monitoring wells. This graph supports the postulate that the elevated tritium seen in NRF groundwater is caused by past discharges of radioactive fluids to the S1W leaching beds. The three wells nearest the leaching beds in the hydrologically downgradient direction contain the highest concentrations of tritium. The concentrations in these wells progressively drop with distance from the leaching beds. The concentrations in the remaining wells cluster in a band that is representative of both local and regional background concentrations. As with the concentrations of many other constituents, the tritium concentration observed in NRF-7 is the lowest of any NRF well.

Figure A-13 uses the same data as Figure A-12 except NRF-11 has been removed. Figure A-13 better shows the stacked nature of the graphs such that the wells further away from the NRF leaching beds contain progressively lower quantities of tritium. This graph again shows that NRF-7 consistently contains the lowest concentrations of tritium. This well is followed by USGS-98 and USGS-99. The graphs from six wells are virtually indistinguishable from one another. These graphs are NRF-8, NRF-12, NRF-13, USGS-12, USGS-97, and USGS-102. With the exception of NRF-6, the wells that produced the data for the remaining graphs (NRF-9 and NRF-10) are downgradient of the S1W leaching beds. NRF-6 is upgradient of the S1W leaching beds adjacent to the IWD.

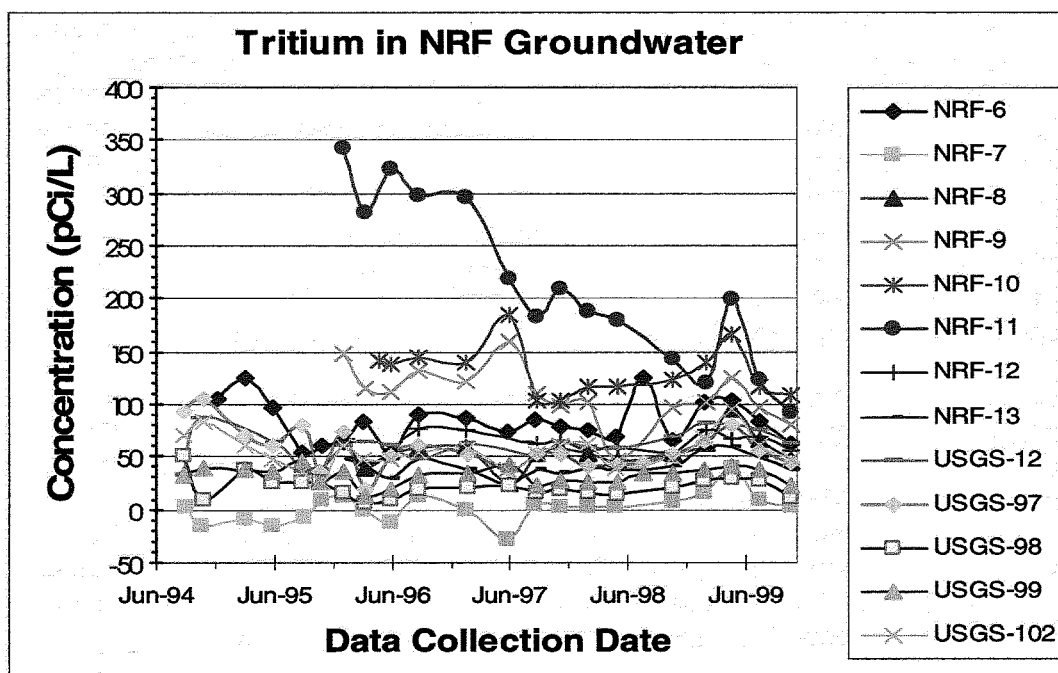


Figure A-12 Tritium in NRF Groundwater

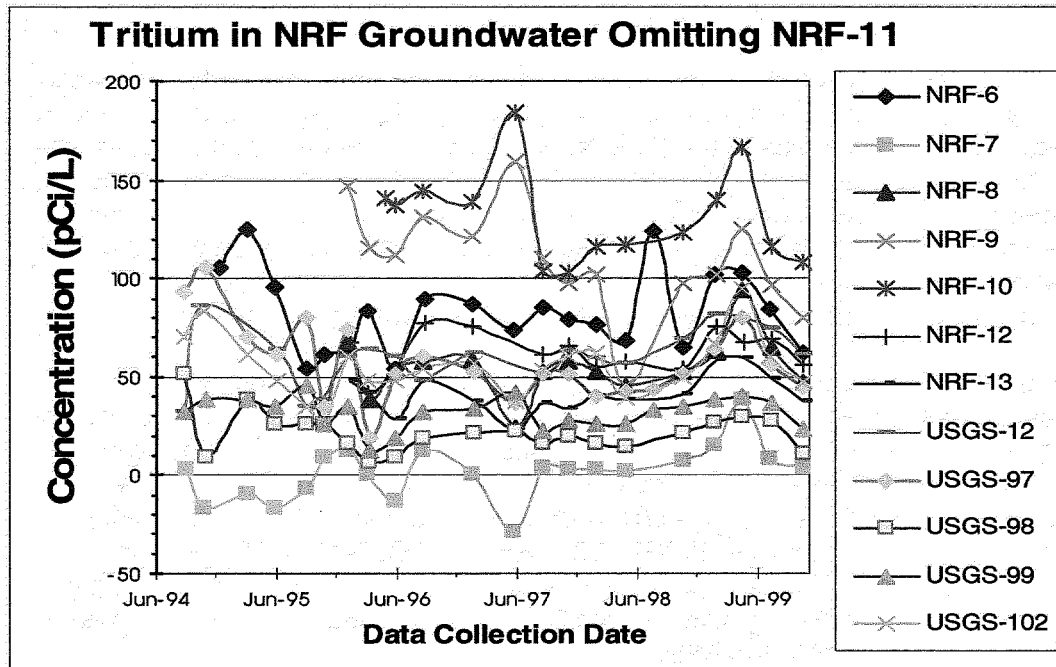


Figure A-13 Tritium in NRF Groundwater Omitting NRF-11

3.3 Additional Trends and Correlations

Trends for the constituents discussed in the preceding sections are expected to be indicative of the characteristics exhibited by other chemical species at NRF. However, observing trends is only one part of the groundwater equation. To fully understand the effects that NRF may have on the SRPA, a direct link between NRF activity and the aquifer must be established. In addition to the samples collected from the groundwater monitoring wells, NRF has been collecting samples from the IWD. Since the IWD and groundwater in the aquifer are hydrologically connected, concentration trends observed in one should be reflected in the other. The following sections discuss the comparison between graphs of IWD chromium and chloride data and graphs of the same constituents in the groundwater.

3.3.1 IWD Chromium and Chloride Concentration Trends

Since 1991, NRF has routinely collected water samples from the outfall of the Industrial Waste Ditch (IWD). There are two primary purposes for collecting these samples. First, these data catalog the nature of the effluent being discharged to the IWD. Second, these data provide a record which verifies that NRF has not discharged significant quantities of pollutants to the IWD, and that NRF is complying with effluent discharge guidelines. A secondary purpose for collecting these data is that they reflect the characteristics of groundwater quality, since the IWD effluent is the major source of aquifer recharge associated with NRF operations.

Figures A-14 and A-15 are graphs of the concentration of chromium and chloride in water collected at the outfall of the IWD. Figure A-14 shows a graph and trend line for IWD chromium data. It shows a decline in effluent chromium concentration since at least 1993 through the end of 1998. For the last several months of 1998, this concentration averaged approximately 3 ppb. The chromium concentration also averaged 3 ppb during 1999 if two anomalous "< 50 ppb" values are not considered (these values were considered to be caused by laboratory error such that the normal lower MDL was not reported). Since October 1998, the trend for IWD chromium concentration has been essentially flat.

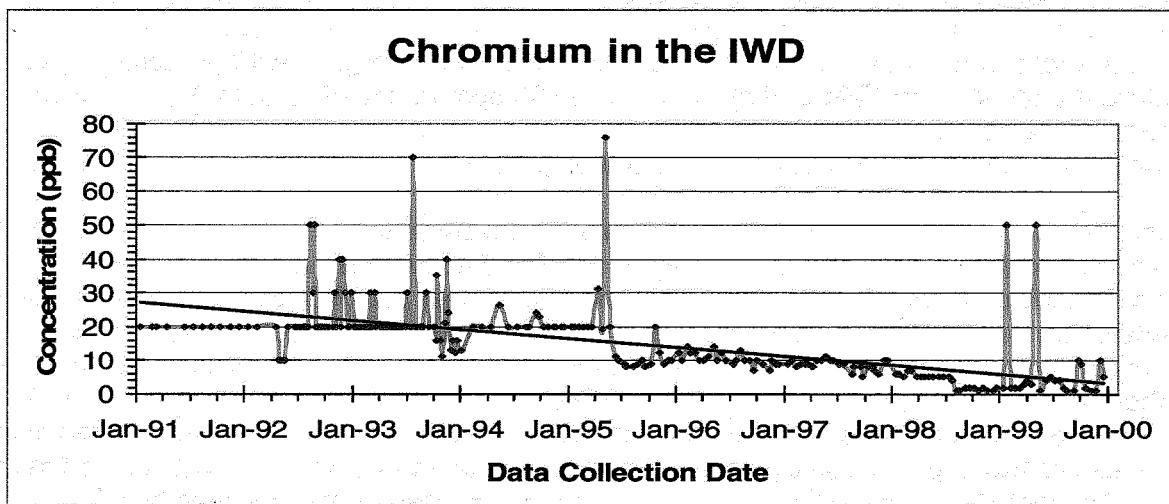


Figure A-14 Chromium in the IWD

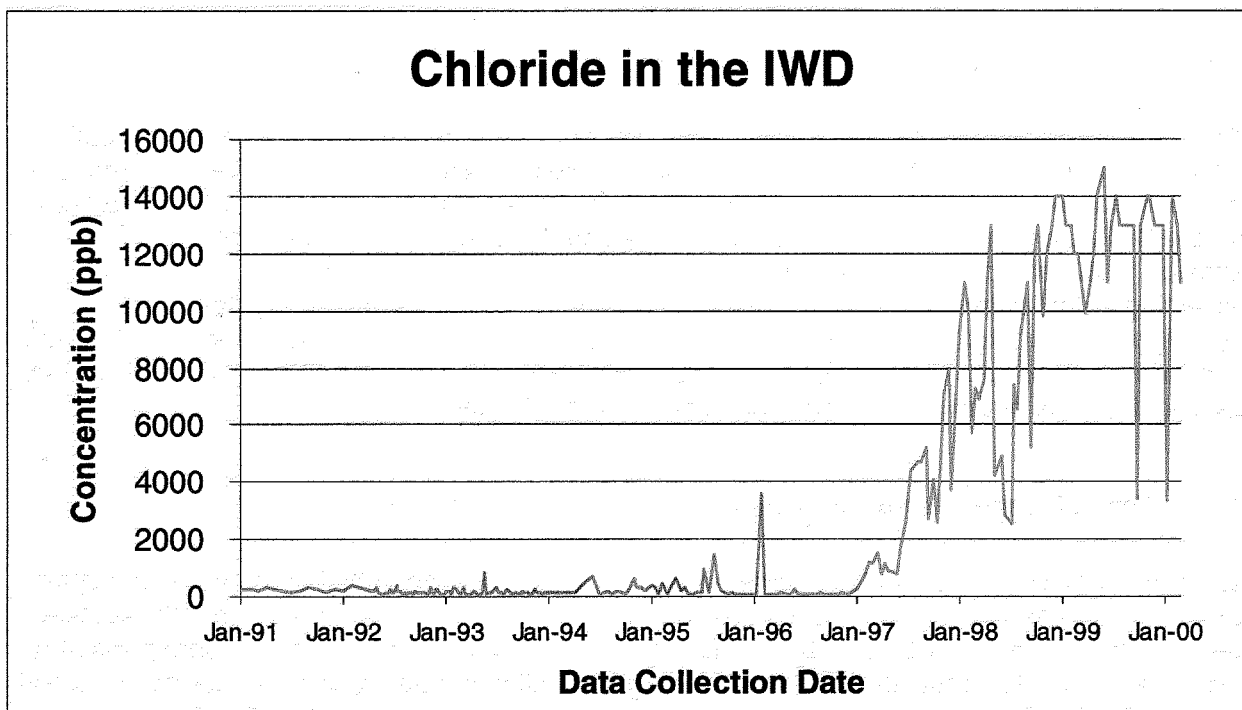


Figure A-15 Chloride in the IWD

The chloride data is more obscure and difficult to interpret. Figure A-15 was constructed using all available chloride concentration values. Figure A-15 shows a graph where chloride concentration is essentially flat prior to 1997. After January 1997, the concentration of chloride in the IWD increased very rapidly and dramatically. In some instances, values were 70 times greater after January 1997 than before. From 1997 through mid-1999, an increasing trend is prevalent. After mid-1999, it appears that effluent chloride concentration may be stabilizing. The interpretation of these same data changes somewhat if certain data are removed.

Several data spikes occurred in chloride between 1991 and 1997. Both the sudden rise in chloride concentration after 1997 and spikes in the data are capable of masking trends. With certain data removed, a more refined trend analysis is possible. Figure A-16 presents a graph with all data after January 1997 and all data above 400 ppm removed. Figure A-16 shows an overall linear decreasing trend up until 1997. When these data were fit with a 6th order polynomial line, an undulating but downward trending line was evident.

In relation to the graphs of the chromium and chloride concentrations in groundwater at NRF-6 specifically, and all wells in general, the graphs described above pose a dilemma. The prevalent trends observed in groundwater concentrations near the IWD are nearly diametrically opposite of trends observed in the IWD effluent. For example, in the graph of NRF-6 data, chloride concentration steadily rises up until March 1997, then begins a precipitous decline. On the other hand, chloride concentrations in the IWD began to rapidly rise during January 1997. Over this time period, chloride concentrations in the IWD have risen from several hundred ppm to in excess of 12,000 ppm. Sufficient time has passed to allow chloride-rich waters to reach the aquifer. The fact that aquifer chloride concentrations have failed to rise indicates that a mechanism yet to be identified is affecting aquifer chloride concentrations. The most likely mechanism is dilution related to nearly continuous flow in the Big Lost River channel. Should

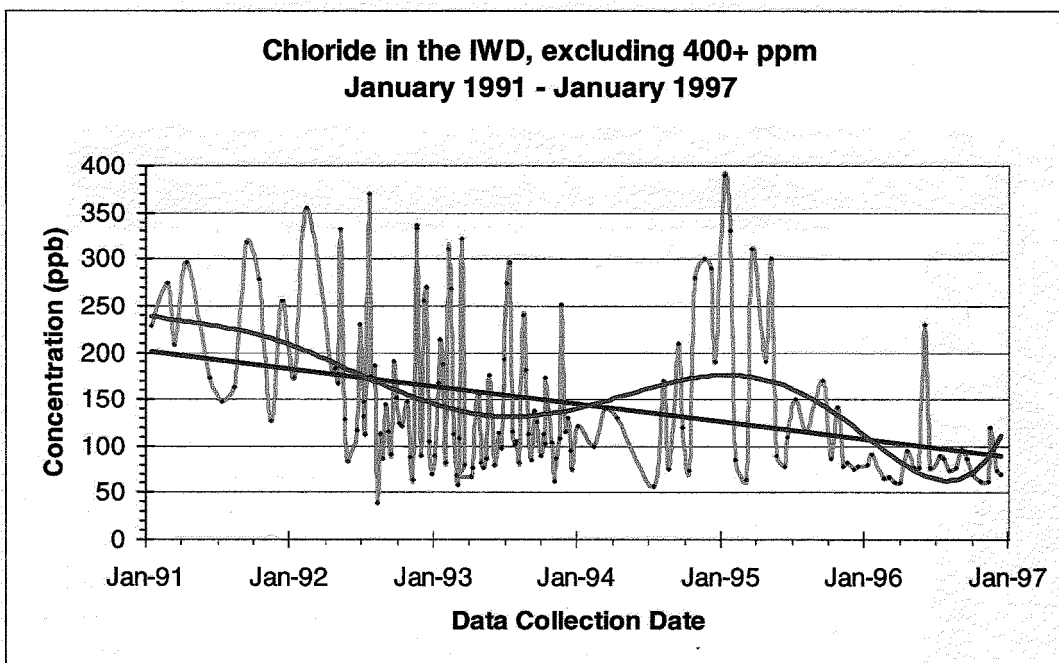


Figure A-16 Chloride in the IWD, Restricted Database

this prove to be the case, this means that in the future, the concentration of most if not all constituents currently monitored by NRF will fall. If this does occur, then caution should be taken in immediately concluding that contaminant release to the SRPA is slowing. This may be true, but the various mechanisms must be considered. Another result of dilution from increased recharge is that the water level in the NRF wells will increase. Since the hydraulic properties of the aquifer surrounding the various wells are not the same, the rate that water will rise in the various wells will be different. This will result in changing localized flow paths at NRF, leading to a redistribution of groundwater contaminants in the aquifer at NRF. A secondary outcome of this is that the concentrations of some constituents may actually rise in some wells.

3.4 Well to Well Comparison

A visual comparison of chromium and chloride graphs comprising data from the same wells was performed to determine if these two constituents, which possess different chemical properties, behave similarly under identical aquifer conditions. Chromium is a constituent that is influenced by the physical properties of the rocks and soil through which it travels. However, chloride travels with water through rocks and soil with little or no retardation. Because of these constituents' different physical properties, they are good indicators of aquifer characteristics.

The degree of similarity between graphs is loosely termed correlation. If two graphs are exactly the same, then the correlation factor is +1. If two graphs are completely opposite, then the correlation factor is -1. For the purpose of this comparison, a numerical analysis is not possible, so only a qualitative description is presented. Given the range of possibilities, the degree of correlation between graphs can be categorized into three main groups. These groups are strongly positive (both graphs trend in the same direction), strongly negative (both graphs trend in opposite directions), and other. The "other" group includes correlations that are weakly

positive, weakly negative, or neutral. Table A-4 illustrates the results of the correlation comparisons.

	Strong Positive	Strong Negative	Weak Positive	Weak Negative	Neutral
NRF-6		X			
NRF-7				X	
NRF-8			X		
NRF-9			X		
NRF-10			X		
NRF-11					X
NRF-12	X				
NRF-13	X				
USGS-12			X		
USGS-97		X			
USGS-98	X				
USGS-99	X				
USGS-102		X			

A comparison of graphs based on the concentration of chromium and chloride constituents in NRF groundwater shows that in almost half the wells, either a strong positive or strong negative correlation exists. In the remaining six wells, the correlation between chromium and chloride constituent graphs is either weak or neutral. A neutral correlation occurs when at least one graph possesses a flat or neutral trend.

Theoretically, a strong positive correlation means some mechanism other than constituent properties is controlling the concentration of that constituent in the groundwater. For NRF this would most likely be the effect of dilution from upgradient aquifer recharge. A strong negative correlation indicates that something linked to the physical properties of the constituents is controlling their concentrations in the groundwater. Weak or neutral correlations may indicate a combination of both mechanisms.

3.5 Conclusions

In general, trends observed in chromium, chloride, and tritium concentrations in the samples collected from the NRF groundwater monitoring wells are coherent with hydrogeological principles, known changes in facility operations, and meteorological patterns. The aquifer concentration of chromium and tritium, the origin of which can be traced to past NRF operations, has declined in most wells. However, chloride concentration has risen in most wells, although several wells display a sharp decline in concentration during the past six or eight quarters. Evidence exists that mounding of water in the aquifer northwest of NRF is beginning to affect NRF wells. Little positive correlation exists between the graphs of chromium and chloride, but the significance of this is not known at this time; it may be due to the difference in chemical properties and the way they are transported in the soil.

4.0 Groundwater Data Analysis

4.1 Introduction

This section provides a snapshot of the current condition of the water in the aquifer beneath NRF. The nature of the 1999 data will be discussed in this section. These data will be discussed in terms as they relate to the upgradient or background concentrations as discussed in Section 1 above. Comparison to data from the previous three years is intended to provide the reader with a frame of reference to assess the relative magnitude of the quantitatively reported values. Short-term trends that may be present can be seen in this table.

In Section 1.1 of this document, local groundwater constituent background values were estimated. It should be noted that background does not necessarily equate with "naturally occurring." In some instances, background is more fairly described as "baseline." This section of the report will use these values as a tool for comparison. Groundwater data collected from the NRF groundwater monitoring wells during 1999 can be categorized into several groups. These groups are discussed below.

Analysis results for groundwater samples collected during 1999 are shown in Attachment 2. That attachment is comprehensive in nature, and contains information on all constituents monitored during 1999. Attachment 7 compares average concentrations for selected constituents from 1996, 1997, and 1998 groundwater analysis results to 1999 results. Attachment 7 is not comprehensive. The selected constituents shown in this table are either the best indicators of aquifer contaminant migration patterns at NRF, or they were released in quantity at NRF as a result of past or current NRF operations.

4.2.1 Constituents near Background or MDL

Eleven groundwater analytes occur at concentrations that are consistently at or near the MDL or local background. These constituents are antimony, arsenic, beryllium, cadmium, mercury, selenium, silver, nitrite, TKN, TOX, and TOC. Concentrations for two of these constituents (cadmium and silver) are below local background concentration in all wells. The concentrations of two constituents slightly exceed background concentrations in one well for antimony and in five wells for TOX. Information gathered during past hydrogeological studies and these data further suggest that antimony, arsenic, beryllium, cadmium, and silver are not naturally occurring groundwater constituents at any significant concentration at this locality. The remaining six constituents may or may not occur naturally in INEEL groundwater. In all cases, these constituents are insignificant groundwater components.

4.2.2 Constituents that Exceed Background or MDL

The concentrations of five groundwater constituents exceed background levels in all but the background wells themselves. These constituents are copper, lead, manganese, nickel, and phosphorus.

The concentration of copper was between MDL (2.0 ppb) and 8.5 ppb in five wells. Concentration of lead was between MDL (1.0 ppb) and 5.2 ppb in all wells. The concentration

of manganese in all wells was at or near MDL (10 ppb) except at NRF-13 where it was 51.5 ppb. The concentration of nickel in all wells is near MDL (10 ppb) except for NRF-10 (23.3 ppb), NRF-12 (18.6 ppb), and NRF-13 (25.5 ppb). The concentration of phosphorus in all wells is above MDL but below 105 ppb (which occurred in NRF-13). Water samples from NRF-10 and NRF-13 have historically possessed a high level of suspended solids, which may be a factor for higher-than-expected concentrations at these wells.

Average copper concentrations in 1999 ranged from 1.8 ppb to 8.5 ppb. If one anomalous value (28.0 ppb) in NRF-11 is not considered, then the average range is 1.8 ppb to 5.0 ppb. These values are not significantly higher than the typical MDL of 2 ppb or local background of 1.7 ppb. Again, the highest average concentration occurred at NRF-13. Copper is not a common groundwater constituent and its occurrence may indicate anthropogenic activity.

Lead is a constituent that does not occur naturally in high concentrations in the waters of the Snake River Plain Aquifer. Both the MDL and the local background concentration for lead is 1 ppb. The lead concentration in most NRF wells is near this concentration; however, the lead concentration in the Regional Downgradient Group wells (USGS-97, USGS-98, and USGS-99) is elevated. The most significant concentration is found in USGS-98. The lead concentration in this well is consistently elevated from quarter to quarter. Between 1994 and 1998, the magnitude of elevated lead concentration in this well steadily fell. Since then, lead concentrations appear to be on the rise again.

Based on the distribution of lead in the NRF groundwater monitoring wells, and on trends observed in the downgradient wells, it appears that NRF may be the source of this lead. This conclusion is difficult to corroborate since no apparent source for the lead is evident. Current NRF procedures strictly control the use of lead, and current release of lead to the environment is prohibited. Elemental lead was historically used at NRF as shielding. Elemental lead is not transported efficiently through the environment. Small quantities of lead were also used in chemistry laboratories and as a fuel additive in gasoline used at NRF. Ionic and organic forms of lead are more mobile in the environment. Elevated lead may also be a product of well construction problems; i.e., soldering of electrical connections.

The MCL for lead is 15 ppb. The average concentration in well USGS-99 has fallen from a high of close to 15 ppb in 1994 to around 5 ppb now.

The elevated presence of manganese in NRF-13 is probably related to historical releases of the constituent to the IWD, and perhaps high suspended solids in the sample water.

Nickel is another constituent that does not commonly occur in quantity in the groundwater. The estimated local background concentration for nickel is approximately 3.6 ppb. The concentration of nickel is slightly above background in most NRF groundwater monitoring wells. Wells that are elevated in nickel are all located closest to the NRF IWD. The presence of nickel in these wells indicates contamination of groundwater by NRF activities. However, nickel concentrations are still well below the federal drinking water standards (100 ppb).

Phosphorus is a common nutrient and is elevated in effluent and sediments of the IWD. The elevated presence of phosphorus in NRF-13 is also probably related to historical releases of the constituents to the IWD, and perhaps high suspended solids in the sample water.

4.2.3 Constituents with Mixed Results

4.2.3.1 Introduction

The remaining groundwater constituents are significantly mixed in relation to their respective MDLs and associated local background concentrations. For simplicity they will be placed into three groups. These groups are miscellaneous metals, salts, and nutrients.

4.2.3.2 Miscellaneous Metals

Included in the miscellaneous metals group are aluminum, barium, chromium, iron, thallium, and zinc. Of these constituents, only aluminum and iron occur naturally in groundwater in any abundance. Barium and chromium are minor groundwater constituents, and thallium and zinc are not naturally occurring groundwater constituents in the SRPA.

The local background concentration for aluminum is approximately 51 ppb. The concentration of aluminum in all but two non-background wells were above this background with average concentrations ranging from 46 ppb (NRF-6) to 2520 ppb (NRF-13). Aluminum was below 250 ppb in all wells except NRF-13, which had an average concentration of 2520 ppb. All quarterly sample results in this well were consistently high. The water from this well has historically possessed a high level of suspended solids. Since aluminum is a naturally occurring element in many of the rock and soil forming minerals, it follows that the groundwater from this well would also be high in aluminum. This explanation alone probably does not account for all the aluminum observed in this well, due to the somewhat elevated aluminum found in other wells. The IWD, which has historically contained elevated levels of aluminum, likely contributed to the results.

Iron exceeds local groundwater background concentrations in 2 of 13 NRF groundwater monitoring wells (NRF-6 and NRF-13). Furthermore, iron concentrations exceed the federal drinking water Secondary Maximum Concentration Limit (SMCL) of 300 ppb in both of these wells. Iron is a constituent that has historically exhibited a propensity to significantly fluctuate in concentration over time. Both of these wells may be affected by effluent from the IWD. Historically, IWD effluent has contained iron as a dissolved constituent. Additionally, NRF-13 is influenced by high-suspended solids as discussed above. The average concentration of iron in NRF-6 is 576 ppb, and in NRF-13, 2683 ppb. Concentrations in both wells appear to be on the rise, and will be watched over the next several years for further trends.

Both the MDL and the local background for barium are 100 ppb. The highest concentration of this constituent in any NRF groundwater monitoring well in 1999 was 174 ppb in NRF-12. Unlike chromium and nickel, NRF-6, NRF-7, and NRF-13 (wells closest to the IWD) contain relatively lower concentrations of barium. Wells downgradient of these sites, (starting with NRF-12) contain progressively less barium. This situation suggests a different contaminant transport mechanism for barium with respect to the IWD. Analysis results indicates that IWD and sewage lagoon effluent contain on average 1120 ppb and 39 ppb barium, respectively.

Chromium is a constituent that has been released to the IWD in the past. Furthermore, sediment samples collected from the IWD channel contain elevated levels of chromium. Past mapping of groundwater chromium concentration shows that the IWD is the source of most NRF-added chromium in the local aquifer. The results of the 1999 monitoring confirm this

conclusion. All wells that are considered to represent background aquifer conditions contain relatively low concentrations of chromium. These wells are (arranged upgradient to downgradient): USGS-12, USGS-97, USGS-98, and USGS-99. Two additional wells possessing relatively low chromium concentrations include NRF-8 and USGS-102. These wells are within 600 feet of each other. The remaining wells all contain chromium concentrations above local background concentrations. In descending order of estimated average concentration these wells are: NRF-13 (73 ppb), NRF-6 (28 ppb), NRF-12 (18 ppb), NRF-11 (15 ppb), NRF-10 (11 ppb), NRF-7 (11 ppb), and NRF-9 (9 ppb). The first three wells on this list are the three wells closest to the IWD.

The local background concentration for thallium is 0.32 ppb. For 1999, the average thallium concentrations for all wells except two were below local background. The exceptions were NRF-6 (2.2 ppb) and NRF-11 (1.4 ppb). In both cases, the elevated concentration was caused by one result, i.e., a value of 8.6 ppb at NRF-6, and a value of 5.2 at NRF-11. The occurrence of thallium in NRF groundwater seems sporadic, and its source is unclear at this time.

The distribution of zinc in the NRF groundwater monitoring wells is similar to that of lead. The average zinc concentration outside of the Regional Downgradient Well group is approximately 17 ppb. The average zinc concentration in the Regional Downgradient Well group is 116 ppb. The local background concentration for zinc is approximately 12 ppb; however, the SMCL for zinc is 5000 ppb. Like lead, zinc was used at NRF, but how zinc was introduced to the environment so as to be seen only in the Regional Downgradient wells is not known. One possibility is that zinc is a product of contamination introduced into the well during construction; i.e., solder for electrical connections.

4.2.3.3 Miscellaneous Inorganic Salts

Included in the miscellaneous salt group are the constituents of calcium, potassium, magnesium, sodium, chloride, and sulfate. All of these constituents occur naturally in abundance in groundwater.

Most constituents contained in the miscellaneous inorganic salt group exceed local background concentrations in all wells except NRF-7 and USGS-98. Historically, NRF has released large quantities of inorganic salts to the SRPA. It follows that a larger percentage of the wells near NRF would contain elevated levels of these salts. Without exception, NRF-6 contains the highest concentrations of inorganic salts. Water from this well is directly fed by effluent from the IWD, which is high in inorganic salt concentration. Conversely, NRF-7 most often contains the lowest concentrations of inorganic salts. When the NRF groundwater monitoring wells are arranged into their respective groups, (e.g., Regional Upgradient, Regional Downgradient, etc.), a familiar pattern emerges. Water from the Regional Upgradient contains the least average organic salt content, then the Regional Downgradient wells, then Site Downgradient wells, and finally, the Effluent System Monitoring wells.

None of the constituents in the miscellaneous inorganic salt group have been assigned an MCL (although chloride and sulfate possess SMCLs). These constituents are not generally believed to pose a threat to human health; however, these constituents are valuable as tracer chemicals for groundwater studies.

4.2.3.4 Miscellaneous Nutrients

Nitrites and nitrates occur naturally, but at low concentrations. Nitrites and nitrates are more commonly from anthropogenic sources, including fertilizers and animal and human wastes. Nitrites plus nitrates exceed background in nine wells (all but NRF-7 and USGS-12, which are background wells, and NRF-13 and USGS-98). Of these nine, the average concentration of nitrites plus nitrates is highest in USGS-97 and lowest in NRF-13. In past years, the distribution of nitrite plus nitrate in groundwater generally decreases with distance from the sewage lagoons. This pattern has changed somewhat in 1999. There appears to be a nitrite plus nitrate high area located just south of NRF. The high dissipates quickly south of NRF. All nitrite plus nitrate values are well below 10,000 ppb, the MCL for these combined constituents.

4.2.3.5 Radioactive Constituents

Currently NRF analyzes groundwater for 5 radioactive parameters: strontium-90, cesium-137, gross alpha, gross beta, and tritium. The average 1999 concentration for each of these constituents was compared with local background. The average concentrations from 1989 to present were also compared with local background. The results of both comparisons are presented in Table A-5. This table shows that average activity for all constituents exceeded background activity in fewer wells during 1999 than over the period 1989 to present (22 versus 14). This may reflect constituent activity that is changing over time, or random statistical fluctuations; however, this same outcome was seen one year ago. All radiological parameter activity except strontium-90 consistently exceeded background activities for both periods. Strontium-90 activity exceeds background activity in the fewest number of wells for both periods.

A well by well comparison shows that in 1999, NRF-6, NRF-10, NRF-11, and NRF-13 exceeded background activities for the greatest number of parameters (4). Over the extended data collection period, four parameters exceeded background activities in all wells except USGS-98 and USGS-99. USGS-98 exceeded background constituent activities for the least number of constituents (never during 1999, and only once for the period 1989 to present). The data in Table A-5 were rearranged and placed into Table A-6. Wells in this table are grouped with respect to their hydrologic relation to NRF. Results shown in Table A-6 create a pattern familiar to NRF. Wells near NRF contain consistently higher constituent concentrations. Wells just downgradient of the facility possess the next highest concentrations. The wells furthest downgradient show the least contamination.

	1999 Data Only					1989 through Present Data				
	Sr-90	Cs-137	Gr. α	Gr. β	H-3	Sr-90	Cs-137	Gr. α	Gr. β	H-3
NRF-6	N	Y	Y	Y	Y	N	Y	Y	Y	Y
NRF-8	N	Y	Y	N	Y	N	Y	Y	Y	Y
NRF-9	N	N	Y	Y	Y	N	Y	Y	Y	Y
NRF-10	N	Y	Y	Y	Y	N	Y	Y	Y	Y
NRF-11	N	Y	Y	Y	Y	N	Y	Y	Y	Y
NRF-12	N	Y	N	Y	Y	Y	Y	Y	Y	Y
NRF-13	N	Y	Y	Y	Y	N	Y	Y	Y	Y
USGS-97	N	Y	Y	N	Y	N	Y	Y	Y	Y
USGS-98	N	N	N	N	N	N	Y	N	N	N
USGS-99	N	N	Y	N	Y	N	Y	Y	N	Y
USGS-102	N	Y	Y	N	Y	N	Y	Y	Y	Y

	1999 Data Only					1989 through Present Data				
	Sr-90	Cs-137	Gr. α	Gr. β	H-3	Sr-90	Cs-137	Gr. α	Gr. β	H-3
NRF-6	N	Y	Y	Y	Y	N	Y	Y	Y	Y
NRF-13	N	Y	Y	Y	Y	N	Y	Y	Y	Y
NRF-12	N	Y	N	Y	Y	Y	Y	Y	Y	Y
NRF-11	N	Y	Y	Y	Y	N	Y	Y	Y	Y
NRF-10	N	Y	Y	Y	Y	N	Y	Y	Y	Y
NRF-9	N	N	Y	Y	Y	N	Y	Y	Y	Y
NRF-8	N	Y	Y	N	Y	N	Y	Y	Y	Y
USGS-102	N	Y	Y	N	Y	N	Y	Y	Y	Y
USGS-97	N	Y	Y	N	Y	N	Y	Y	Y	Y
USGS-98	N	N	N	N	N	N	Y	N	N	N
USGS-99	N	N	Y	N	Y	N	Y	Y	N	Y

Y: Yes, this concentration exceeded local background concentration.

N: No, this concentration did not exceed local background concentration.

The following analysis considers all data collected from 1989 to present.

The average Strontium-90 activity in all NRF groundwater monitoring wells is below the local background activity of 0.29 pCi/L except in NRF-12. The average activity in this well is dominated by results obtained early in 1997. In 1997, quarterly results were 5 to 10 times larger than they have been for the past seven quarters. The cause of this period of unusually high values is not known. The INEEL background level for strontium-90 is considered to be approximately 5.0 pCi/L. All NRF strontium activity levels are below the INEEL background levels. Strontium-90 activity is not a problem in NRF groundwater.

Cesium-137 activity is above the local background activity of 0.02 pCi/L in all wells. The 2 Sigma Total Error associated with Cesium-137 is 0.85 pCi/L, creating a range of between 0 and 0.87 pCi/L. In all instances where background is exceeded, results are within the 2 Sigma value of 0.87 pCi/L. The 2 Sigma value is an expression of the variance or uncertainty associated with the data. Given a normal distribution, 95% of the data should fall within two standard deviations of the mean. This indicates the possibility that the activity observed in all

NRF wells is a statistical variation of background. Like strontium-90, cesium-137 is not a problem in NRF groundwater.

The average local background activity for gross alpha is 1.96 pCi/L with a 2 sigma of 0.68 pCi/L; therefore, the range for local background is 1.28 pCi/L to 2.64 pCi/L. The INEEL background for gross alpha ranges from 2.1 to 3.0 pCi/L. Average gross alpha activity in all wells except USGS-98 exceeds average local background activity. Additionally, all wells except NRF-8, NRF-12, USGS-98, and USGS-99 exceed the 2-sigma activity. The highest average gross alpha activity is found in NRF-9 at 3.27 pCi/L, which also exceeds the upper INEEL background range. Contouring these data creates the pattern of elevated gross alpha shown in Figure A-17. This pattern suggests that both the A1W and S1W leaching beds may influence the amount of gross alpha in the aquifer. Each area corresponds to one of the NRF leaching beds. A review of historical records shows that only small quantities of gross alpha radioactivity were released to the leaching beds. Calculations indicate that the maximum released activity would be approximately 0.3 pCi/L. This is well below the 3.27 pCi/L observed. NRF believes that the difference is due to the presence of natural alpha emitters in the groundwater. Alpha emitting radionuclides occur naturally at low concentrations in both soils and the basalt beneath NRF, and vary widely from place to place. Large quantities of water passing through these soils would likely leach some of these constituents from the soils and basalt. Residual perched water releases to the aquifer may introduce small quantities of gross alpha to groundwater. Since the MCL for gross alpha is 15 pCi/L, and because the suspected elevated levels of gross alpha are likely from naturally occurring sources, this constituent is not considered to be a problem at NRF.

The average local background activity for gross beta is 3.73 pCi/L. The 2 sigma activity level was determined to be 0.90 pCi/L, creating an expected local background range of 2.83 pCi/L to 4.63 pCi/L. The upper value was exceeded in five wells with the following maxima: NRF-6 (7.00 pCi/L), NRF-9 (4.68 pCi/L), NRF-11 (4.77 pCi/L), NRF-12 (4.80 pCi/L), and NRF-13 (7.00 pCi/L). NRF-6, NRF-12, and NRF-13 are the three wells hydrologically nearest the IWD. Although unconfirmed, the elevated gross beta activity in these wells may be related to elevated levels of salts observed in these wells. NRF-6, NRF-13, and NRF-12 contain the 1st, 2nd, and 3rd highest levels of salts among all NRF wells, respectively. Small amounts of potassium chloride are almost always associated with sodium chloride in nature. A small percentage of naturally occurring potassium is radioactive and a beta emitter; therefore, it would be expected that the wells with the highest salt content would also contain the highest levels of gross beta. The INEEL background level for gross beta is 5.1 pCi/L. The MCL for gross beta in groundwater is 50 pCi/L. Based on these results, this constituent is not considered to be a problem at NRF.

Tritium is a constituent that historical documents show has been released to the environment at NRF. Evidence gathered during the NRF Comprehensive RI/FS indicates that the local background concentration for tritium is approximately 28 pCi/L; however, the 2-sigma value is 19 pCi/L, which generates an expected local background range of 9 pCi/L to 47 pCi/L. Based on published reports at the INEEL (Orr et. al.), regional tritium background ranges from 75 to 150 pCi/L. Average tritium groundwater concentrations at NRF exceed local background concentrations in 10 of 11 wells (upgradient wells USGS-12 and NRF-7 excluded). In addition, the local background upper limit 2-sigma concentration was exceeded by the 1999 average concentration in all but three wells, NRF-13, USGS-98, and USGS-99. Finally, the regional background concentration range upper value was exceeded only in NRF-11; the average tritium activity in this well is 213 pCi/L and has been declining for the past several years. The MCL for tritium is 20,000 pCi/L.

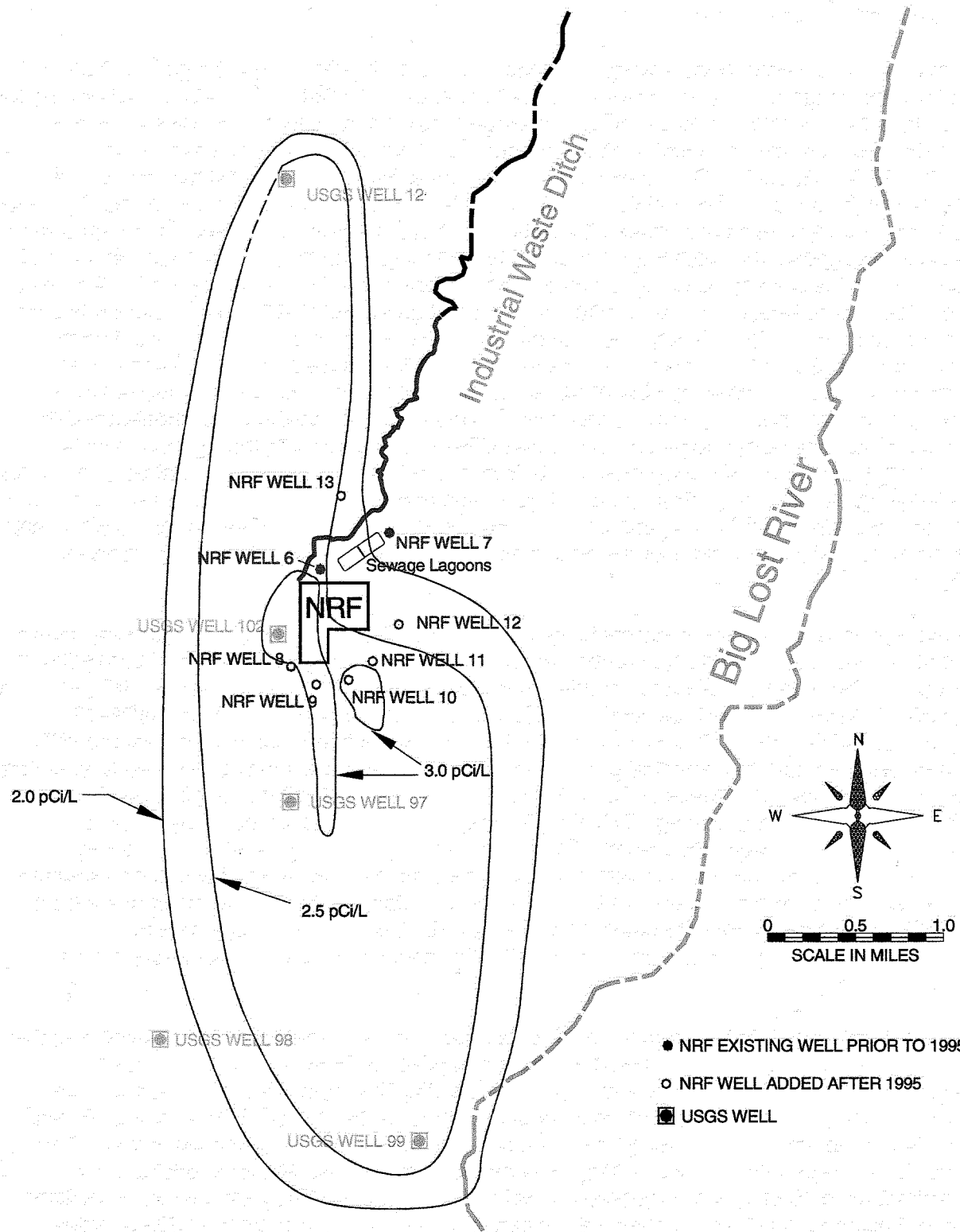


Figure A-17 Distribution of Gross Alpha in the Aquifer Near NRF

5.0 Analysis and Interpretation Summary

The data discussed in this report covers basic topics in hydrology and groundwater monitoring. Data from ongoing sampling efforts were presented, along with current climatological and water table elevation information. A summary of the conclusions of this report is presented below.

Compared to pre-established INEEL background concentrations for selected chemical and radiological constituents, the comparable local background concentrations tend to be lower. The INEEL concentrations are derived using a wider-ranging set of values that have an upper end component not necessarily representative of conditions near NRF. Additionally, waters sampled by NRF are closer to the recharge sources. Using NRF local background concentrations for qualitative analysis of NRF groundwater provides a more conservative approach to groundwater monitoring.

Long term analysis of NRF groundwater constituents provides insight into what to expect from future groundwater monitoring efforts. Based on current results, chromium and tritium concentrations in groundwater are on a downward trend for most wells. Several exceptions exist; however, these exceptions are minor or their strength and longevity is not known. Groundwater chloride concentrations appear to be on the rise. This trend is not entirely unexpected; however, since chloride is a tracer constituent in groundwater and migrates more quickly than its metallic counterparts, attention will be given to trends in metallic constituents in the future.

Analysis results of NRF groundwater over the past 11 years demonstrate that activities at NRF have not significantly degraded the quality of the Snake River Plain Aquifer near NRF. No annual average concentration for any constituent has exceeded primary MCLs (regulatory levels). A few individual sample exceedences occurred: chromium exceeded its primary MCL twice and lead exceeded its MCL three times since 1990. In each case, the occurrences of these excessive concentrations were brief and did not constitute a trend. The concentrations for aluminum, iron, and manganese frequently exceeded secondary MCLs (aesthetic water quality parameters which are not enforced at NRF).

The climate at NRF appears to have been slowly changing over the last 28 years. The three most pronounced changes are that temperatures appear to be rising slowly, recent precipitation appears to be on the increase, and individual weather events are becoming more pronounced. Because of the volatile nature of climate, these results are considered preliminary and further study of trends will continue. Should the current trends continue, significant changes to local hydrologic conditions may occur. Current climatic trends may increase the risk for localized flooding in the future, although the risk of a major flood of the Big Lost River affecting NRF is low. NRF is outside the 100-year flood plain of the river.

The elevation of the water table at and near NRF is currently on the rise. This change appears to be partially related to long-term climate changes, and partially to shorter term cyclical events. Furthermore, a comparison between aquifer data and climate data indicates that aquifer response to climate change may be more rapid than previously believed. The Snake River Plain Aquifer water table has on average been declining since the mid-1960s. It is unknown whether the current rebound will restore the aquifer water table to its historic levels. Although the possibility exists for enhanced mobilization of known groundwater contaminants due to water table changes, no evidence as yet shows that this is happening.

6.0 Data Gaps

This report supplies information about the hydrology and geology pertaining to NRF, and supports consideration of changes to current monitoring efforts. Another purpose of this report is to identify data gaps in the areas of hydrology, geology, and groundwater monitoring.

One of the most pressing issues at the INEEL today is that of flooding potential. Two INEEL studies were initiated to examine this issue. Both studies were funded through DOE, but each study approaches the problem of flooding potential from a different perspective. These studies are documented in two reports (Ostenaa et. al., 1999; Ostenaa, 1998). Both studies concentrate on the area around the RWMC, CFA, Test Reactor Area (TRA), and Idaho Nuclear Technology Company (INTEC). While these documents speak of NRF, they do not specifically address the flooding potential at NRF. This may be a data gap.

Past studies have generated flow parameters that can be applied to different facilities; however, the unique parameters at NRF have not been examined. Specific data gaps may include:

- 1) Detailed elevation profiles north and south of NRF. These profiles would begin at the channel of the current Big Lost River and end in the elevated basalt flows west of NRF.
- 2) Evaluation of channel geomorphology, including tracing abandoned flow channels upstream, and noting their elevation and their proximity to the existing Big Lost River flow channel. Man-made canals and their relation to the present and past flow channels of the Big Lost River would be considered in determining possible flood flow paths.
- 3) Application of these data to flood models specific to NRF that would integrate the affects of elevation, morphology, and infiltration. Precipitation recurrence intervals would be prepared from existing data, and used to predict future flooding hazards.